Quantum Optics and Photonics Division
Fachverband Quantenoptik und Photonik (Q)

Prof. Dr. Jürgen Eschner
Universität des Saarlandes
D-66123 Saarbrücken, Germany
juergen.eschner@physik.uni-saarland.de

Prof. Dr. Klemens Hammerer
Universität Innsbruck
A-6020 Innsbruck, Austria
klemens.hammerer@uibk.ac.at

Overview of Invited Talks and Sessions

(Lecture halls P 2, P 3, P 4, P 5, P 7, P 10, and P 11; Poster Philo 1. OG and 2. OG)

Invited Talks

Q 8.1	Mon	17:00–17:30	P 3	**Heterogeneous Quantum Photonics: A Platform for Quantum Sensing, Networking, and Transduction** — •Samuel Gyger
Q 11.3	Mon	17:30–18:00	P 7	**Quantum radiometry metrology for quantum photonics technologies** — •Angela Gamouras
Q 12.1	Mon	17:00–17:30	P 10	**Topological pumping and quantum information** — •Konrad Viebahn
Q 20.1	Tue	11:00–11:30	P 7	**Entangled photons from GaAs quantum dots in tunable circular Bragg resonators** — •Armando Rastelli
Q 21.1	Tue	11:00–11:30	P 10	**Interfacing with Quantum Information Processors—From Readout to Control** — •Benjamin Lienhard
Q 22.1	Tue	11:00–11:30	P 11	**Exploring nonlinear optics with x-rays** — •Dietrich Krebs
Q 30.1	Wed	14:30–15:00	P 1	**Shedding light on nuclear spins: from collective states to a quantum memory** — •Mete Atature
Q 34.1	Wed	14:30–15:00	P 5	**Spectral Peaked Optical Frequency Comb for Highly Sensitive Cavity Ring-down Spectroscopy** — •Hideki Tomita
Q 35.1	Wed	14:30–15:00	P 10	**Quantum field simulation on bosonic platforms** — •Tobias Haas
Q 45.1	Thu	11:00–11:30	P 3	**Quantum geometry in plasmonic metasurfaces and signatures of collective quantum phenomena** — •Javier Cuerda
Q 46.1	Thu	11:00–11:30	P 4	**Squeezed Light and Optimal Phase Estimation for Quantum Metrology** — •Mojdeh Shikhali Najafabadi
Q 48.1	Thu	11:00–11:30	P 7	**Quantum teleportation with remote quantum dots in a metropolitan hybrid quantum network** — •M. B. Rota
Q 56.1	Thu	14:30–15:00	P 3	**Quantum logic control of transition metal and molecular ions** — •Fabian Wolf
Q 59.1	Thu	14:30–15:00	P 7	**High-Speed Quantum Key Distribution using Single Photons from Defects in Hexagonal Boron Nitride** — •Serkan Ateş
Q 59.6	Thu	16:00–16:30	P 7	**Metropolitan Quantum Key Distribution based on Room Temperature Single Photon Source** — •Haoran Zhang
Q 60.1	Thu	14:30–15:00	P 10	**Towards entangling distributed registers of atoms** — •Ben Lanyon
Q 70.1	Fri	11:00–11:30	P 3	**Totally destructive many-body interference beyond bosons and fermions** — •Gabriel Dufour
Q 73.1	Fri	11:00–11:30	P 7	**Microwave quantum communication with rare-earth spin ensembles** — •Nadezhda Kukharchyk

Invited Talks of the joint Symposium SAMOP Dissertation Prize 2026 (SYAD)

See SYAD for the full program of the symposium.

SYAD 1.1	Mon	14:30–15:00	RW 1	**What graphs can tell us about quantum information** — •Kiara Hansenne
SYAD 1.2	Mon	15:00–15:30	RW 1	**Realization of alkaline-earth circular Rydberg qubits in optical tweezer arrays** — •Christian Hölzl
SYAD 1.3	Mon	15:30–16:00	RW 1	**Pattern Formation and Supersolid-like Sound Modes in a Driven Superfluid** — •Nikolas Liebster

SYAD 1.4	Mon	16:00–16:30	RW 1	**Harnessing time-frequency qudits using integrated nonlinear processes** — •Laura Serino

Invited Talks of the joint Symposium Classical and Quantum Structured Light (SYSL)

See SYSL for the full program of the symposium.

SYSL 1.1	Mon	17:00–17:30	P 1	**Structured-light-matter interaction for quantum cryptography and nanoscale modal control** — •Eileen Otte, Asma Fallah, William A. Jarrett, Alexander D. White, Giovanni Scuri, Seungjun Eun, Nicholas A. Guesken, Hossein Taghinejad, Jelena Vuckovic, Mark L. Brongersma
SYSL 1.2	Mon	17:30–18:00	P 1	**Attosecond Structured Light Pulses with Topology and Polarization Textures** — •Carlos Hernandez-Garcia
SYSL 1.3	Mon	18:00–18:30	P 1	**Structured light for the creation of squeezed multiplets to encode quantum information in trapped ions** — •Corina Révora, Christian Tomás Schmiegelow, Juan Pablo Paz
SYSL 1.4	Mon	18:30–19:00	P 1	**Atomic Magnetometry Employing Vector Light Beams** — •Riaan Philipp Schmidt, Richard Aguiar Maduro, Anton Peshkov, Sonja Franke-Arnold, Andrey Surzhykov

Invited Talks of the joint Symposium Spin-Boson Models (SYSB)

See SYSB for the full program of the symposium.

SYSB 1.1	Tue	11:00–11:30	RW 1	**Tailoring the quantum dynamics of spins with bosonic baths** — •Giovanna Morigi
SYSB 1.2	Tue	11:30–12:00	RW 1	**Spins, Qubits, and Bosons** — •Guido Burkard
SYSB 1.3	Tue	12:00–12:30	RW 1	**Spin-boson models under strong ac-driving** — •Milena Grifoni
SYSB 1.4	Tue	12:30–13:00	RW 1	**Kibble-Zurek scenario for melting of discrete time crystals** — •Phatthamon Kongkhambut, Hans Kessler, Roy D. Jara Jr., Jayson G. Cosme, Andreas Hemmerich

Invited Talks of the joint Symposium Selected Highlights of AMOP in Austria (SYAU)

See SYAU for the full program of the symposium.

SYAU 1.2	Wed	11:15–11:45	RW 1	**Supersolidity: When Superfluid Flow Meets Crystalline Order** — •Francesca Ferlaino
SYAU 1.3	Wed	11:45–12:15	RW 1	**Charged Helium Nanodroplets: A Cold Laboratory for Molecular Ions** — •Elisabeth Gruber
SYAU 1.4	Wed	12:15–12:45	RW 1	**Advances in Broadband Saturation Spectroscopy: Towards Probing New Physics in the Mid-Infrared** — •Oliver Heckl
SYAU 1.5	Wed	12:45–13:15	RW 1	**Precision laser spectroscopy of the Thorium-229 nuclear transition** — •Thorsten Schumm

Invited Talks of the joint Symposium Light and Chirality: From Fundamentals to Applications (SYLC)

See SYLC for the full program of the symposium.

SYLC 1.1	Wed	14:30–15:00	RW 1	**Enantio-sensitive molecular compass** — P. M. Flores, S. Carlstroem, S. Patchkovskii, M. Ivanov, V. Mujica, A. F. Ordonez, •O. Smirnova
SYLC 1.2	Wed	15:00–15:30	RW 1	**Conjugation, chirality and optical activity** — •Matthew Fuchter
SYLC 1.3	Wed	15:30–16:00	RW 1	**Gas-phase spectroscopy of chiral molecules** — •Anne Zehnacker, Etienne Rouquet, Valéria Lepère, Gustavo Garcia, Laurent Nahon
SYLC 1.4	Wed	16:00–16:30	RW 1	**Toward a low-energy test of the parity symmetry via precise mid-IR spectroscopy of cold chiral molecules** — Agathe Bonifacio, Sahil Viel, Raphaël Hahn, Minh Nhut Ngo, Marylise Saffre, Yuhao Liu, Wenling Dong, Etienne Cantin, Olivier Lopez, Anne Amy-Klein, Mathieu Manceau, •Benoît Darquié

Invited Talks of the joint Symposium One-Dimensional Quantum Many-Body Systems between Bose and Fermi Statistics (SYMB)

See SYMB for the full program of the symposium.

SYMB 1.1	Thu	14:30–15:00	P 1	**Exploring gauge theories for 1D anyons in Raman-coupled Bose gases** — •Leticia Tarruell
SYMB 1.2	Thu	15:00–15:30	P 1	**Non trivial particle exchange in one dimension: The anyon Hubbard model and beyond** — •André Eckardt
SYMB 1.3	Thu	15:30–16:00	P 1	**Exotic Quantum Statistics in Strongly Interacting 1D Bose Gases** — •Hanns-Christoph Nägerl
SYMB 1.4	Thu	16:00–16:30	P 1	**Dipolar gases in triangular ladders** — •Luis Santos

Invited Talks of the joint Symposium Tests of Fundamental Physics with AMO Systems (SYFP)

See SYFP for the full program of the symposium.

SYFP 1.1	Fri	11:00–11:30	RW 1	**Searches for new bosons with isotope shift spectroscopy and the thorium nuclear transition** — •Elina Fuchs
SYFP 1.2	Fri	11:30–12:00	RW 1	**Precision spectroscopy of muonic atoms** — •Randolf Pohl
SYFP 1.3	Fri	12:00–12:30	RW 1	**Quantum-Controlled Molecules for Fundamental Physics and Quantum Science** — •Nicholas Hutzler
SYFP 1.4	Fri	12:30–13:00	RW 1	**Testing Baryon Asymmetry with Antiprotons** — •Stefan Ulmer

Invited Talks of the joint Symposium Laser Driven X-Rays: Generation and Application (SYLX)

See SYLX for the full program of the symposium.

SYLX 1.1	Fri	14:30–15:00	RW 1	**Laserstrahlquellen als Treiber für Sekundärstrahlquellen** — •Torsten Mans, Dominik Bauer, Thomas Metzger, Dominik Ertel, Claus Schnitzler, Tino Eidam
SYLX 1.2	Fri	15:00–15:30	RW 1	**Development and Integration of Novel LPP Radiation Sources for Enhanced Characterization and Industrial Application** — Lion Günster, Luka Petersen, Philip Mosel, Peer Biesterfeld, Sven Fröhlich, Jose Mapa, Greta Paruschke, Pia Koopmann, Bianca Iwan, Uwe Morgner, •Milutin Kovacev
SYLX 1.3	Fri	15:30–16:00	RW 1	**Near-relativistic ytterbium fiberlaser plasma source for high-flux hard X-ray generation from a liquid-metal jet** — •Robert Klas, Maximilian Benner, Mohammed Almassarani, Maximilian Karst, Lucas Eisenbach, Philipp Gierschke, Warunya Röder, Arno Klenke, Jan Rothhardt, Jens Limpert
SYLX 1.4	Fri	16:00–16:30	RW 1	**Laser-driven X-ray generation for industrial applications** — •Johannes Maximilian Ebert, Klaus Bergmann, Sarah Klein, Martin Traub, Jochen Vieker, Stephan Herman Wissenberg, Hans-Dieter Hoffmann

Sessions

Q 1.1–1.5	Mon	11:45–13:00	P 2	**Ultracold Matter I – Fermions (joint session Q/A)**
Q 2.1–2.5	Mon	11:45–13:00	P 3	**Nanophotonics and Integrated Photonics I**
Q 3.1–3.5	Mon	11:45–13:00	P 5	**Quantum Technologies – Enabling Technologies**
Q 4.1–4.5	Mon	11:45–13:00	P 10	**Quantum Computing and Simulation I**
Q 5.1–5.5	Mon	11:45–13:00	P 11	**Laser Cooling and Trapping**
Q 6.1–6.3	Mon	11:45–12:45	N 1	**Ultra-cold Plasmas and Rydberg Systems I (joint session A/Q)**
Q 7.1–7.8	Mon	17:00–19:00	P 2	**Ultracold Matter II – Bosons (joint session Q/A)**
Q 8.1–8.7	Mon	17:00–19:00	P 3	**Nanophotonics and Integrated Photonics II**
Q 9.1–9.7	Mon	17:00–18:45	P 4	**Open Quantum Systems and Spin-Boson Systems I**
Q 10.1–10.8	Mon	17:00–19:00	P 5	**Quantum Technologies – Photon Detectors and Sources**
Q 11.1–11.7	Mon	17:00–19:00	P 7	**QuanTour I – Single Photons & Foundations**
Q 12.1–12.6	Mon	17:00–18:45	P 10	**Quantum Computing and Simulation II**
Q 13.1–13.8	Mon	17:00–19:00	P 11	**Nuclear Clocks**

Q 14.1–14.7	Mon	17:00–19:00	N 3	**Precision Spectroscopy of Atoms and Ions I (joint session A/Q)**
Q 15.1–15.7	Mon	17:00–19:00	N 6	**Precision Mass Spectrometry (joint session MS/Q)**
Q 16.1–16.8	Tue	11:00–13:00	P 2	**Ultracold Matter III – Fermions (joint session Q/A)**
Q 17.1–17.8	Tue	11:00–13:00	P 3	**Photonics and Biophotonics I**
Q 18.1–18.8	Tue	11:00–13:00	P 4	**Photon BEC**
Q 19.1–19.8	Tue	11:00–13:00	P 5	**Quantum Technologies – Ion Traps**
Q 20.1–20.7	Tue	11:00–13:00	P 7	**QuanTour II – Multi-photon Effects & Entanglement**
Q 21.1–21.7	Tue	11:00–13:00	P 10	**Quantum Computing and Simulation III**
Q 22.1–22.7	Tue	11:00–13:00	P 11	**Nuclear and X-Ray Quantum Optics**
Q 23.1–23.8	Tue	11:00–13:15	P 105	**Cold Molecules (joint session MO/Q)**
Q 24.1–24.8	Tue	11:00–13:00	N 1	**Ultra-cold Atoms, Ions and BEC I (joint session A/Q)**
Q 25.1–25.7	Tue	11:00–13:00	N 3	**Precision Spectroscopy of Atoms and Ions II (joint session A/Q)**
Q 26.1–26.19	Tue	17:00–19:00	Philo 1. OG	**Poster – Ultrashort Pulses and Strong Fields (joint session K/Q)**
Q 27.1–27.29	Tue	17:00–19:00	Philo 1. OG	**Poster – Precision Spectroscopy of Atoms and Ions (joint session A/Q)**
Q 28.1–28.35	Tue	17:00–19:00	Philo 2. OG	**Poster – Quantum Optics**
Q 29.1–29.39	Tue	17:00–19:00	Philo 2. OG	**Poster – Quantum Technologies I**
Q 30.1–30.7	Wed	14:30–16:30	P 1	**QuanTour III – Spin Physics & Coherence**
Q 31.1–31.8	Wed	14:30–16:30	P 2	**Ultracold Matter IV – Bosons, Rydberg Systems, and Others (joint session Q/A)**
Q 32.1–32.8	Wed	14:30–16:30	P 3	**Photonics and Biophotonics II**
Q 33.1–33.8	Wed	14:30–16:30	P 4	**Cavity QED, QED, and Spin-Boson Systems I**
Q 34.1–34.7	Wed	14:30–16:30	P 5	**Quantum Technologies – Sensing I**
Q 35.1–35.7	Wed	14:30–16:30	P 10	**Quantum Computing and Simulation IV**
Q 36.1–36.8	Wed	14:30–16:30	P 11	**Matter Wave Interferometry and Metrology I**
Q 37.1–37.7	Wed	14:30–16:30	N 1	**Ultra-cold Atoms, Ions and BEC II (joint session A/Q)**
Q 38.1–38.7	Wed	14:30–16:30	N 3	**Precision Spectroscopy of Atoms and Ions III (joint session A/Q)**
Q 39.1–39.5	Wed	17:00–19:00	Philo 1. OG	**Poster – Cold Molecules (joint session MO/Q)**
Q 40.1–40.23	Wed	17:00–19:00	Philo 1. OG	**Poster – Photonics**
Q 41.1–41.28	Wed	17:00–19:00	Philo 2. OG	**Poster – Quantum Technologies II & Laser Technology**
Q 42.1–42.32	Wed	17:00–19:00	Philo 2. OG	**Poster – Ultracold Matter (joint session Q/A)**
Q 43.1–43.16	Wed	17:00–19:00	Philo 2. OG	**Poster – Quantum Systems**
Q 44.1–44.8	Thu	11:00–13:00	P 2	**Laser Technology and Applications**
Q 45.1–45.7	Thu	11:00–13:00	P 3	**Plasmonics and Metasurfaces**
Q 46.1–46.7	Thu	11:00–13:00	P 4	**Open Quantum Systems II**
Q 47.1–47.8	Thu	11:00–13:00	P 5	**Quantum Technologies – Sensing II**
Q 48.1–48.7	Thu	11:00–13:00	P 7	**QuanTour IV – Building Blocks**
Q 49.1–49.8	Thu	11:00–13:00	P 10	**Quantum Communication, Networks, Repeaters, & QKD I**
Q 50.1–50.8	Thu	11:00–13:00	P 11	**Matter Wave Interferometry and Metrology II**
Q 51.1–51.7	Thu	11:00–13:00	N 1	**Ultra-cold Atoms, Ions and BEC III (joint session A/Q)**
Q 52.1–52.6	Thu	11:00–13:00	N 2	**Ultra-cold Plasmas and Rydberg Systems II (joint session A/Q)**
Q 53.1–53.7	Thu	11:00–13:00	N 3	**Precision Spectroscopy of Atoms and Ions IV (joint session A/Q)**
Q 54	Thu	13:15–14:15	P 10	**Members' Assembly**
Q 55.1–55.8	Thu	14:30–16:30	P 2	**Optomechanics**
Q 56.1–56.7	Thu	14:30–16:30	P 3	**Quantum Optics and Control I**
Q 57.1–57.8	Thu	14:30–16:30	P 4	**Open Quantum Systems III**
Q 58.1–58.8	Thu	14:30–16:30	P 5	**Quantum Technologies – Color Centers I**
Q 59.1–59.6	Thu	14:30–16:30	P 7	**QuanTour V – Protocols**
Q 60.1–60.7	Thu	14:30–16:30	P 10	**Quantum Communication, Networks, Repeaters, & QKD II**
Q 61.1–61.8	Thu	14:30–16:30	P 11	**Matter Wave Interferometry and Metrology III**
Q 62.1–62.8	Thu	14:30–16:30	N 1	**Ultra-cold Atoms, Ions and BEC IV (joint session A/Q)**
Q 63.1–63.8	Thu	14:30–16:30	N 3	**Precision Spectroscopy of Atoms and Ions V (joint session A/Q)**
Q 64.1–64.42	Thu	17:00–19:00	Philo 1. OG	**Poster – Ultra-cold atoms, ions and BEC (joint session A/Q)**

Q 65.1–65.9	Thu	17:00–19:00	Philo 1. OG	**Poster – Ultra-cold plasmas and Rydberg systems (joint session A/Q)**
Q 66.1–66.33	Thu	17:00–19:00	Philo 2. OG	**Poster – Quantum Technologies III**
Q 67.1–67.31	Thu	17:00–19:00	Philo 2. OG	**Poster – Quantum Information**
Q 68.1–68.15	Thu	17:00–19:00	Philo 2. OG	**Poster – Precision Measurement (joint session Q/A)**
Q 69.1–69.7	Fri	11:00–12:45	P 2	**Collective Effects and Disordered Systems**
Q 70.1–70.7	Fri	11:00–13:00	P 3	**Quantum Optics and Control II**
Q 71.1–71.8	Fri	11:00–13:00	P 4	**Cavity QED and QED II**
Q 72.1–72.7	Fri	11:00–12:45	P 5	**Quantum Technologies – Color Centers II**
Q 73.1–73.7	Fri	11:00–13:00	P 7	**Quantum Technologies – Solid State Systems**
Q 74.1–74.8	Fri	11:00–13:00	P 10	**Quantum Information – Concepts and Methods**
Q 75.1–75.6	Fri	11:00–12:30	P 11	**Quantum Systems between Bose and Fermi Statistics**
Q 76.1–76.7	Fri	11:00–13:00	N 1	**Ultra-cold Atoms, Ions and BEC V (joint session A/Q)**
Q 77.1–77.7	Fri	14:30–16:15	P 2	**Photonics – 3D Printing**
Q 78.1–78.7	Fri	14:30–16:15	P 3	**Quantum Optics and Control III**
Q 79.1–79.8	Fri	14:30–16:30	P 4	**Cavity QED and QED III**
Q 80.1–80.7	Fri	14:30–16:15	P 5	**Quantum Technologies – Color Centers III**
Q 81.1–81.8	Fri	14:30–16:30	P 10	**Quantum Communication, Networks, Repeaters, & QKD III**
Q 82.1–82.8	Fri	14:30–16:30	P 11	**Matter Wave Interferometry, Metrology, and Fundamental Physics IV**
Q 83.1–83.6	Fri	14:30–16:00	N 1	**Ultra-cold Atoms, Ions and BEC VI (joint session A/Q)**
Q 84.1–84.4	Fri	14:30–15:30	N 3	**Precision Spectroscopy of Atoms and Ions VI (joint session A/Q)**

Members' Assembly of the Quantum Optics and Photonics Division

Thursday 13:15–14:15 P 10

Q 1: Ultracold Matter I – Fermions (joint session Q/A)

Time: Monday 11:45–13:00 Location: P 2

Q 1.1 Mon 11:45 P 2

Reduction of pair correlations below the background value in ultracold Fermi gases — •Nikolai Kaschewski[1], Axel Pelster[1], and Carlos A. R. Sá de Melo[2] — [1]University of Kaiserslautern-Landau, Kaiserslautern, Germany — [2]Georgia Institute of Technology, Atlanta, Georgia, USA

For cold atomic gases in the superfluid state, Quantum Monte Carlos (QMC) methods predicted already two decades ago that the anomalous pair correlation function in 3D drops below the uncorrelated background value of one for intermediate distances [1]. Recent progress in developing continuous quantum gas microscopes [2-4] allowed to directly measure pair correlations in 2D [5], confirming this prediction. Although this has sparked new interest into this phenomenon, it lacks until now an analytic explanation.

Against this background, we study two-particle correlation functions in two-dimensional Fermi gases at zero temperature. By allowing the order parameter to adjust to local perturbations, we self-consistently predict a drop of pair correlations below unity, agreeing well with QMC calculations [1] and measurements [5] for weak interactions. The results provide an analytic explanation for the experimentally observed dip based on coupling the density response to induced collective modes, mediating interactions between Cooper pairs. [1] C. Lobo et al., Phys. Rev. Lett. 97, 100405 (2006) [2] J. Xiang et al., Phys. Rev. Lett. 134, 183401 (2025) [3] R. Yao et al., Phys. Rev. Lett. 134, 183402 (2025) [4] T. de Jong et al., Phys. Rev. Lett. 134, 183403 (2025) [5] C. Daix et al., arXiv:2504.01886 (2025)

Q 1.2 Mon 12:00 P 2

Developing a programmable quantum gas microscope — •Sarah Waddington[1,2], Saumya Shah[1,2], Isabelle Safa[1,2], Constanze Vogel[1,2], Rodrigo Rosa-Medina[1,2], and Julian Léonard[1,2] — [1]Institute of Science and Technology Austria (ISTA), Am Campus 1, 3400 Klosterneuburg, Austria — [2]Atominstitut TU Wien, Stadionallee 2, 1020 Wien, Austria

Ultracold atoms in optical lattices offer a versatile platform for simulating and probing strongly correlated quantum matter. While quantum gas microscopy techniques have enabled single-site resolution, key remaining challenges of the field are still posed by rigid lattice configurations and slow cycle times. Here, we present an update on the development of our new quantum gas microscope for fermionic and bosonic lithium atoms. Our approach relies on atom-by-atom assembly in small lattice systems by means of auxiliary optical tweezers, combined with all-optical cooling techniques to facilitate sub-second experimental cycles. The holographic projection of a blue-detuned, short-spacing lattice will provide reconfigurability and fast tunneling dynamics, leading to diverse research avenues for our new project, from the simulation of Bose- and Fermi-Hubbard models with unconventional geometries to strongly correlated topological phases.

Q 1.3 Mon 12:15 P 2

Nonequilibrium correlations in the transverse field Ising model under resonant periodic driving — •Larissa Schwarz[1], Simon Balthasar Jäger[2], Imke Schneider[1], and Sebastian Eggert[1] — [1]University of Kaiserslautern-Landau — [2]University of Bonn

We study the non-equilibrium dynamics of the one-dimensional transverse field Ising model under periodic driving. Using Floquet theory, we derive the steady states of the driven model for a fixed driving amplitude and identify Floquet modes that emerge from strong resonant dressing of the eigenstates of the undriven system. Studying the real time evolution and comparing it with Floquet theory, we find that the system evolves into superpositions of Floquet states, where the ramping rate of the driving amplitude influences the occupation of higher Floquet bands. This behaviour is compared to analytical predictions from a modified Landau-Zener theory. We also compute the two-point correlation functions, which show oscillations in position space that can be tuned with the driving frequency. Our results highlight how periodic driving can be used to create exotic non-equilibrium states.

Q 1.4 Mon 12:30 P 2

Programmable Assembly of Ground State Fermionic Tweezer Arrays — •Marcus Culemann[1], Francesco Testi[1], Jin Zhang[1], Naman Jain[1], and Philipp Preiss[1,2] — [1]Max-Planck Institute of Quantum Optics, Garching, Germany — [2]Munich Center for Quantum Science and Technology, Munich, Germany

Quantum simulation with ultracold fermions in optical lattices provides unique insights into the microscopic details of strongly interacting quantum many-body systems. For non-equilibrium experiments, the choice of the initial atomic configuration is usually limited to a small set of accessible states such as Mott-insulators or charge density waves. Arrays of optical tweezers offer a capable extension to this toolbox by using their dynamic reconfigurability to assemble quantum systems in an optical lattice atom-by-atom.

We demonstrate the preparation of arbitrary spin- and density-resolved product states of single atoms within an 8x8 optical tweezer array. Specifically, we showcase preparation of anti-ferromagnets with engineered defects like domain-walls in the tweezer array and report on recent progress on the state assembly in the lattice. Combined with fast single-exposure spin- and site-resolved imaging, these advancements enable new directions in out-of-equilibrium physics within the Fermi-Hubbard model as well as fermionic quantum information processing.

Q 1.5 Mon 12:45 P 2

Probing Choi superconductivity in a fermionic quantum simulator — •Marnix Barendregt[1,2], Si Wang[1,2], Petar Bojovic[1,2], Johannes Obermeyer[1,2], Dorothee Tell[1,2], Immanuel Bloch[1,2,3], and Titus Franz[1,2] — [1]Max Planck Institute of Quantum Optics, Garching, Germany — [2]Munich Center for Quantum Science and Technology, Munich, Germany — [3]Ludwig Maximilian University of Munich, Munich, Germany

Ultracold fermionic atoms in optical lattices have become a powerful platform for exploring the Fermi-Hubbard model with site-resolved resolution. Many strongly correlated phases exhibit spontaneous strong-to-weak symmetry breaking, but detecting this experimentally is challenging because its signature depends quadratically on the system's density matrix, requiring two identical copies of the state. Here, we introduce an alternative approach based on the Choi doubled Hilbert space representation, where the second copy is generated numerically on a classical computer. In this framework, the Rényi-2 correlator maps onto a superconducting pairing correlator. We probe this "Choi superconductivity" by measuring site-resolved occupation numbers in a lithium-6 quantum gas microscope. These measurements open new avenues for using quantum gas microscopes to identify strongly correlated phases such as Dirac spin liquids and 1+1D conformal field-theory states.

Q 2: Nanophotonics and Integrated Photonics I

Time: Monday 11:45–13:00 Location: P 3

Q 2.1 Mon 11:45 P 3

Adaptive Molecular Systems in Coherent Nanophotonic Neural Networks — •Peter Lazarowicz[1,2,3], Ole Körner[1,2,3], Robin Conrad[1,2,3], and Carsten Schuck[1,2,3] — [1]University Of Münster, Schlossplatz 2, 48149 Münster — [2]CeNTech, Heisenbergstraße 11, 48149 Münster — [3]Center for Soft Nanoscience, Busso-Peus-Straße 10, 48149 Münster

Neuromorphic computing is a field that has seen both rapid popularisation and development in recent years, with nanophotonic neural networks showing promise in bypassing the Von Neumann bottleneck and vastly improving computational efficiency.

We investigate adaptive molecular systems as a basis for optical neural network architectures, exploiting photoisomerisation and saturable absorption mechanisms to induce the nonlinear responses that are necessary for deep learning approaches. We demonstrate integration of azobenzene photoswitches and doped phthalocyanine complexes in photonic circuits enabling fast, parallelisable photonic processing.

Q 2.2 Mon 12:00 P 3

Fabrication of LNOI Nanostructures For High Quality Quantum PICs — •Georgii Grechko[1], Tobias Feuerbach[1], Junyu Guan[1,2], Roman Kolesov[1], and Joerg Wrachtrup[1,3] — [1]3rd Institute of Physics, University of Stuttgart, Stuttgart, Germany — [2]University of Science and Technology of China, Hefei 230026, PR.China — [3]MPI for Solid State Research, Stuttgart, Germany

Lithium Niobate on Insulator (LNOI) is well established wafer-scale nanophotonic platform. Owning a unique set of properties, the material exhibits electro-optical tunability and second-order optical nonlinearity. Overall LNOI is a strong contender in the race for becoming the main platform for large-scale quantum nanophotonics, on par with silicon-on-insulator and silicon nitride. This research further enriches the technological toolkit for LNOI platform by introducing a novel nanofabrication framework based on metal hard-mask formation via lift-off and CF4 based RIE-ICP dry etching. We addressed and eliminated the key drawbacks of CF4 plasma etching that originally motivated the shift toward alternative etching methods. Key process advantages include a mask-edge smoothing effect resulting in exceptionally smooth sidewalls of fabricated structures, etch rates exceeding 60 nm/min with selectivity of 7-10 over hard mask Showcasing our fabrication approach, we demonstrate high-Q photonic crystal and Fabry-Perot cavities, manufactured using the reported method, featuring native second-harmonic generation (SHG). At submission, the highest Q-factor reached 500,000; higher values may be achieved by the time of presentation.

Q 2.3 Mon 12:15 P 3

Integrated photonics for quantum communications on a CubeSat — •Jonas Pudelko[1,2], Ömer Bayraktar[1,2], Luca Vill[1,2], Mathias Kühn[1,2], Joost Vermeer[1,2], Winfried Boxleitner[3], Stefan Petscharnig[3], Christoph Pacher[3], Gerd Leuchs[1,2], and Christoph Marquardt[1,2] — [1]Max Planck Institute for the Science of Light, Erlangen — [2]Chair of Optical Quantum Technologies, Friedrich-Alexander-Universität Erlangen-Nürnberg, Staudtstr. 7 / A3, Erlangen — [3]AIT Austrian Institute of Technology GmbH, Center for Digital Safety & Security, Vienna, Austria

Satellite based quantum key distribution enables worldwide secure communication with distinct advantages over fiber links. The profitability of commercial systems highly depends on the size, weight and power demands of the required payloads.

Our CubeSat payload demonstrates a source for weak modulated coherent states as well as a quantum random number generator based on homodyne measurements of the quantum mechanical vacuum state on a single 10 cm x 10 cm PCB with a power consumption of 4 W. The high level of integration is enabled by two Indium-Phosphide photonic integrated circuits and custom designed electronic driving circuits.

The payload was launched in 2024 as part of the QUBE mission. Here, we will present our in-orbit characterization measurements and the findings from the ongoing optical downlink campaign.

Q 2.4 Mon 12:30 P 3

Characterisation of a photonic integrated circuit-based QKD transmitter — •Joost Vermeer[1,2], Ömer Bayraktar[1,2], Jonas Pudelko[1,2], Kevin Günthner[1,2], and Christoph Marquardt[1,2] — [1]Chair of Optical Quantum Technologies, Friedrich-Alexander-Universität Erlangen-Nürnberg, Staudtstr. 7 / A3, Erlangen — [2]Max Planck Institute for the Science of Light (MPL), Staudtstr. 2, Erlangen

Quantum key distribution (QKD) offers a new way to provide secure communication. Miniaturising the required optical components allows us to implement it in many more situations, including satellites. This would allow us to overcome the range limitation of fiber-based systems and lead to worldwide secure communication.

One method of miniaturising optical systems is using photonic integrated circuits (PIC), where many optical components are integrated on a single chip. We have designed a 4×8 mm^2 indium-phosphide PIC, which can act as a transmitter for phase-based BB-84 QKD. It consists of a pulsed laser, an IQ modulator to turn each laser pulse into a pair of pulses with a phase difference determined by a quantum random number generator, and an intensity modulator containing multiple semiconductor optical amplifiers to set the required output intensity.

Integrating all of these components close together can increase the strength of unwanted interactions between them. Using both external measurement devices and detectors integrated in the PIC, we characterise the PIC to investigate how strong these effects are.

Q 2.5 Mon 12:45 P 3

Photoluminescence excitation spectroscopy of color-centers in diamond waveguides integrated in AlGaN/AlN nanophotonic circuits — •Grigory Kornilov[1], Alok Gokhale[1], Lea Rektorschek[1], Domenica Bermeo[1,2], Marco Stucki[1,2], Francesco Intravaia[1], Kurt Busch[1], Sinan Gündoğdu[1,2], Tommaso Pregnolato[1,2], and Tim Schröder[1,2] — [1]Department of Physics, Humboldt-Universität zu Berlin, Berlin, Germany — [2]Ferdinand-Braun-Institut (FBH), Berlin, Germany

Hybrid photonic integrated circuits (PICs) with embedded solid-state quantum emitters enable compact and scalable quantum devices. We have recently proposed a novel platform for integrated photonics based on AlGaN grown on AlN on sapphire. By incorporating air gaps in the structure of the circuits, diamond nanophotonic devices can subsequently be suspended across them, creating hetero-integrated waveguides which enable efficient in- and out-coupling of light. Manufacturing the nanophotonic circuits in a "racetrack" geometry allows transmission experiments to be performed in a single confocal setup. Using this approach, the coupling efficiency of diamond waveguides to the underlying AlGaN/AlN structures is investigated. In addition, photoluminescence excitation measurements are conducted to study the optical properties of individual nitrogen-vacancy centers embedded in the diamond.

Q 3: Quantum Technologies – Enabling Technologies

Time: Monday 11:45–13:00 Location: P 5

Q 3.1 Mon 11:45 P 5

Compact and fully-integrated ZERODUR vacuum system for quantum sensing applications — •David Latorre Bastidas[1], Sören Boles-Herresthal[1], Nora Bidzinski[2], Bojan Hansen[2], André Wenzlawski[1], Ortwin Hellmig[2], Klaus Sengstock[2], and Patrick Windpassinger[1] — [1]Institute of Physics, Johannes Gutenberg University Mainz — [2]Institute for Quantum Physics, University of Hamburg

In the context of advancing quantum sensing technologies for real-life applications, we propose a compact, fully integrated, passively pumped ultra-high vacuum chamber based on ZERODUR. This glass-ceramic has a negligible coefficient of thermal expansion (CTE) and ultra-low helium permeability, making it an ideal candidate for vacuum chambers.

This contribution presents the demonstration of a Rubidium-87 magneto-optical trap inside a compact home-built ZERODUR vacuum chamber, using a nanostructured diffraction grating chip (gMOT) and a PCB for the generation of the quadrupole magnetic field. The chamber integrates UV-activated alkali metal dispensers and non-evaporable getters, eliminating the need for electrical feedthroughs. Results are presented on the characterization of the vacuum chamber, where the MOT is used as a pressure sensor, as well as on the MOT performance. This system approach sets the foundation for future compact quantum sensors, offering significant potential for practical, real-world applications.

Q 3.2 Mon 12:00 P 5

Topology-Optimized Two-Port Beam Splitters for Quantum Photonic Integrated Circuits — Shiang-Yu Huang[1], •Alessandro Ciorra[1], Jonas Höpker[1], Jeldrik Huster[1], Yannick Augenstein[2,3], Carsten Rockstuhl[2,3], and Stefanie Barz[1,4] — [1]Institute for Functional Matter and Quantum Technologies, University of Stuttgart, 70569 Stuttgart, Germany — [2]Institute of Theoretical Solid State Physics, Karlsruhe Institute of Technology, 76131 Karlsruhe, Germany — [3]Institute of Nanotechnology, Karlsruhe

Institute of Technology, 76021 Karlsruhe, Germany — [4]Center for Integrated Quantum Science and Technology (IQST), University of Stuttgart, 70569 Stuttgart, Germany

In quantum information processing, two-port beam splitters serve as the essential elements where multiphoton interference occurs, which enables the generation of photonic quantum states. Meanwhile, topology optimization has recently advanced integrated photonics by enabling ultracompact, high-performance devices through efficient exploration of large design spaces and the discovery of non-intuitive geometries. In this work, we explore how different constraints in the topology optimization, such as device footprint, minimum feature size, etc., affect the performance of the beam splitter designs. We characterize the beam splitters using single-photon and two-photon measurements. We also reconstruct each devices transfer matrix and analyze the linear transformations they implement. Our results provide insight into how the inverse-designed beam splitters operate and highlight their potential for scalable and densely integrated quantum photonic systems.

Q 3.3 Mon 12:15 P 5

Microwave Generation for the Manipulation of Rubidium Ensembles — •Valeria Camacho Molina, Maike Diana Lachmann, and Tobias Bartusch — Airbus Defence and Space GmbH , Willy-Messerschmitt-Strasse 1, 82024 ,Taufkirchen , Germany

Ultra-cold atomic ensembles, with their microscopic coherence times, narrow momentum distributions, and highly controllable quantum states, are essential for high-precision measurements and advanced quantum technologies. Precise control of both the internal and motional states of the atoms is critical for reproducible and accurate performance.

In this work, a microwave subsystem is implemented to drive evaporative cooling of a Rubidium-87 atomic ensemble in a magnetic trap to achieve Bose*Einstein condensation. Additionally, after condensation, the system is used for state preparation, transferring the atoms in well-defined internal states to ensure reproducible and controlled experimental conditions. The subsystem integrates low-phase-noise frequency generation, agile frequency control, and thermally stable electronics to achieve consistent and reproducible performance. Its compact, robust, and low-power design makes it well suited for space-deployable quantum sensors, where reliability and environmental robustness are critical.

Q 3.4 Mon 12:30 P 5

Entropy-Based Complexity Characterization of Integrated Photonic Physical Unclonable Functions — •Himadri Sahoo, Rick Bevers, Daan J. de Ruiter, Lars van der Hoeven, Daan P. Stellinga, Matthias C. Velsink, and Pepijn W. H. Pinkse — MESA+ Institute for Nanotechnology, University of Twente, P.O. Box 217, 7500 AE Enschede, the Netherlands

Integrated photonic Physical Unclonable Functions (PUFs) offer high intrinsic complexity due to fabrication-induced disorder and multimode interference. We present an entropy-based framework to quantify their information content using repeated time-domain optical responses. From current amplitude-only spectra, we extract lower bounds on effective entropy and identify correlations limiting independent degrees of freedom. Numerical simulations based on these experimental spectra are employed to visualize response variations and support the evaluation of different entropy estimators. To achieve a more complete complexity assessment, we propose complementary vector network analyzer measurements providing phase-resolved transfer functions with higher spectral resolution. This combined experimental-numerical approach advances complexity determination in photonic hardware security primitives.

Q 3.5 Mon 12:45 P 5

Verification of Electron-Photon Entanglement — •Phila Rembold[1], Alexander Preimesberger[1,2], Sergei Bogdanov[1,2], Santiago Beltrán-Romero[1,2], Dennis Rätzel[1,2,3], Isobel C Bicket[1,2], Elizabeth Agudelo[1], Nicolai Friis[1], and Philipp Haslinger[1,2] — [1]Atominstitut, TU Wien, Stadionallee 2, 1020 Vienna, Austria — [2]University Service Centre for Transmission Electron Microscopy, TU Wien, Wiedner Hauptstraße 8-10/E057-02, 1040 Vienna, Austria — [3]ZARM, University of Bremen, 28359 Bremen, Germany

Entanglement, a central concept in quantum physics, describes correlations between particles that cannot be explained classically. While routinely verified in photonic and atomic systems, direct experimental evidence in transmission electron microscopy (TEM) has been missing. We report the detection of position*momentum entanglement between single free electrons and photons generated via coherent cathodoluminescence in a TEM. The method relies on a general separability bound: for classically correlated particles, the product of the conditional variances in relative position and total momentum cannot fall below a fixed limit. Using coincidence-based ghost imaging, adapted from quantum optics, we measure both spatial and momentum correlations of electron-photon pairs. The observed variance product is significantly below the classical limit, confirming entanglement. This result links the well-developed tools of photonic quantum optics with the capabilities of electron microscopy, offering a route toward quantum-enhanced imaging at the atomic scale.

Q 4: Quantum Computing and Simulation I

Time: Monday 11:45–13:00 Location: P 10

Q 4.1 Mon 11:45 P 10

Mølmer-Sørensen Gates Robust to AC Shifts — •Erin Feldkemper[1], Victor Martinez Lahuerta[1], Christian Ospelkaus[1], Naceur Gaaloul[1], and Klemens Hammerer[2,3,4] — [1]Institut für Quantenoptik, Leibniz Universität Hannover — [2]Institut für Theoretische Physik, Universität Innsbruck — [3]Institut für Theoretische Physik, Leibniz Universität Hannover — [4]IQOQI Österreichische Akademie der Wissenschaft

Fast and high-fidelity quantum gates are essential for scaling trapped-ion quantum computing, and their optimization has become increasingly important. One of the key challenges is mitigating the AC shift, which can arise in both laser-driven and microwave-driven gates, introducing errors that degrade the performance. In this theory work, we focus on microwave-driven Mølmer-Sørensen gates and specifically the impact of the AC Zeeman shift on the gate performance. To this end, we derived an effective Hamiltonian including leading-order AC corrections. In order to reduce the noise, we focus on two methods. The first consists in using spin echoes, which exploits the fact that the shift is linear with the S_z spin component. The other method is to time-dependently control the parameters of the gate and optimize them using optimal control theory. To evaluate the fidelity of the protocols, we use Kraus operators as a figure of merit for a good quantum channel. Both of these methods are exploited, compared to each other, and would ultimately be combined to improve the gate precision.

Q 4.2 Mon 12:00 P 10

Tailoring spin–spin coupling of trapped ions by electrode shape optimization — •Kais Rejaibi, Patrick H. Huber, and Christof Wunderlich — Universität Siegen, Walter-Flex-Straße 3, 57072 Siegen

Trapped ions are a leading physical platform for quantum information processing. When scaling up such quantum processors, it is advantageous to control the qubit's coherent dynamics by directly using electronic signals in the (quasi-)direct current (DC) and radio frequency (RF) regime, without conversion of these signals into the optical domain. N-qubit gates ($N \geq 2$) controlled by electronic signals are possible when applying a static or RF magnetic gradient field in a Paul trap. The matrix characterizing the interaction between N qubits can be tailored, for instance, by modifying the trapping potential confining the ions. We developed a numerical method to design and optimize electrode shapes that determine the trapping potential in 2D ion traps. From this we obtain the ion positions, mode structure, and effective interaction matrix. These results enter a cost function that measures how well a given design reproduces the desired interaction pattern under constraints such as maximum voltage and trap depth. By minimizing this cost function we obtain electrode geometries that favour the chosen interaction with low control-voltage requirements. While we focus on linear trap segments, the same approach can also be applied to more elements such as junctions in scalable ion-trap chips.

Q 4.3 Mon 12:15 P 10

Scaling-up a trapped-ion quantum computer using MAGIC — •Saptarshi Biswas[1], Ivan Boldin[1], Benjamin Bürger[1], Friederike J. Giebel[3,4], Radhika Goyal[2], Patrick H. Huber[1], Eike Iseke[3,4], Lukas Kilzer[2], Nila Krishnakumar[3,4], Rodolfo M. Rodriguez[1], Tobias Pootz[2], Kais Rejaibi[1], David Stuhrmann[2], Nora D. Stahr[2,4], Jacob Stupp[2,4], Konstantin Thronberens[3,4], Celeste Torkzaban[2], Pedram Yaghoubi[1], Christian Ospelkaus[2,3,4], and Christof Wunderlich[1] — [1]Department of Physics, School of Science and Technology, University of Siegen, 57068 Siegen, Germany — [2]Gottfried Wilhelm Leibniz Universität, Hannover, Germany — [3]Physikalisch-Technische Bundesanstalt, Braunschweig, Germany — [4]Laboratory of Nano and Quantum-Engineering, Hannover, Germany

We present the status of a cryogenic (4K) experimental set-up for quantum computing with radio frequency (RF)-controlled trapped ions. It incorporates a novel micro-structured planar Paul trap with integrated micromagnets, and we report on the characterization of such a trap. Also, progress in developing laser cooling techniques for mixed Yb^+-Ba^+ crystals is reported.

Q 4.4 Mon 12:30 P 10

Towards a cryogenic trapped ion quantum processor with cryogenic control electronic — •Dorna Niroomand[1], Daniel Busch[1], Eike Iseke[2,3], Nila Krishnakumar[2,3], Max Glantschnig[5], Leon Dixius[4], Alexander Meyer[6], Garima Saraswat[7], Matthias Brandl[4], Friederike J. Giebel[2,3], Vadim Issakov[6], Michael Johanning[7], and Christof Wunderlich[1] for the ATIQ SIEGEN-Collaboration — [1]Department of Physics, School of Science and Technology, University of Siegen, 57068 Siegen, Germany — [2]Physikalisch-Technische Bundesanstalt, Braunschweig, Germany — [3]Laboratory of Nano and Quantum-Engineering, Hannover, Germany — [4]Infineon Technologies AG, Neubiberg, Germany — [5]Infineon Technologies Austria AG, Villach, Austria — [6]Institut für CMOS Design,TU Braunschweig, Braunschweig, Germany — [7]eleQtron GmbH, Siegen, Germany

Trapped ion quantum computing platforms in cryogenic vacuum have the advantage of providing extreme high vacuum (XHV) allowing for long ion storage times, even in the relatively shallow trapping potential of surface-electrode Paul traps. Furthermore, anomalous heating of trapped ions is strongly suppressed. Here, we will discuss the progress towards building and operating a cryogenic quantum demonstrator that includes low-noise cryogenic electronics to precisely control trapping potentials and enable shuttling of ions. En route towards scalable trapped ion quantum processors, multiple generations of microfabricated surface-electrode traps with integrated magnets and cryogenic control electronics are investigated in this platform.

Q 4.5 Mon 12:45 P 10

Experimental characterization of all-to-all-coupled trapped-ion quantum registers — •Markus Nünnerich, Patrick H. Huber, Dorna Niroomand, and Christof Wunderlich — Dept. of Physics, School of Science and Technology, University of Siegen, 57068 Siegen, Germany

For quantum computing and -simulation, high connectivity between qubits mediated by long-range interactions can be beneficial to speed up running times of algorithms and to enable efficient error correction. Here, we experimentally characterize computational quantum registers of varying size with all-to-all interaction between qubits. The qubits are encoded into hyperfine states of laser-cooled trapped $^{171}Yb^+$ ions. The ions interact via magnetic gradient induced coupling (MAGIC) and all coherent operations on qubits are performed using RF radiation. We carry out measurements on individual addressing of interacting qubits within a computational register (crosstalk), qubit read-out, and the all-to-all interaction between qubits. Furthermore, we entangle subsets of the qubit register using bare-state qubits or dressed-state qubits. In addition, we describe how fluctuations of the trapping potential affect the interaction between qubits.

Q 5: Laser Cooling and Trapping

Time: Monday 11:45–13:00 Location: P 11

Q 5.1 Mon 11:45 P 11

A tweezer system for trapping and addressing single atoms in an optical cavity — •Micha Kappel, Raphael Benz, Sebastián Alejandro Morales Ramirez, Daniel Reigel, Maurizio Trigilia, Luis Weiss, Vincent Beguin, Leon Layer, Violet Ruf, and Stephan Welte — 5. Physikalisches Institut, Universität Stuttgart, Pfaffenwaldring 57, 70569 Stuttgart, Germany

A key building block for a quantum internet is a versatile multi-qubit quantum network node that can process and distribute quantum information. An array of neutral atoms, coupled to an optical cavity, is a promising hardware platform for implementing such a node. In this architecture, the cavity serves as the interface between the stationary atomic qubits and the flying photonic qubits. Leveraging optical tweezers, the atoms in the array are positioned and addressed within the cavity mode.

We present a setup featuring two acousto-optical deflectors that generates multiple optical tweezers for trapping and addressing arrays of ^{87}Rb atoms. Using this setup, we plan to trap atoms both within the cavity mode and next to it. This way, we can counteract the inevitable intra-cavity atom losses by reloading atoms from an atom reservoir outside the cavity. We discuss the experimental techniques and challenges associated with our optical setup, and describe the software developed for the project.

Q 5.2 Mon 12:00 P 11

Hybrid Trapping of Cold Atoms with Surface Forces and Blue-Detuned Evanescent Light on a Nanophotonic Waveguide — •Riccardo Pennetta, Antoine Glicenstein, Philipp Schneeweiss, Jürgen Volz, and Arno Rauschenbeutel — Department of Physics, Humboldt Universitaet zu Berlin, 12489 Berlin, Germany

We demonstrate a novel hybrid nanophotonic trap for cold neutral atoms, leveraging surface forces for attraction and blue-detuned evanescent light for repulsion. We attribute the attractive potential to a combination of Casimir-Polder interactions and electrostatic charges distributed on the waveguide surface. Despite the trap's shallow depth, we efficiently load atoms into it via adiabatic transfer from a conventional two-color dipole trap. Remarkably, the hybrid trap supports a long atomic storage time of 140(9) ms and exhibits a Ramsey coherence time of 16.8(2) ms, the latter exceeding significantly previous reports for nanophotonic systems. Our results pave the way for further exploration of atom-surface interactions at the nanoscale and illustrate the potential of harnessing surface forces to enhance storage and coherence times for atoms coupled to nanophotonic waveguides. This advancement offers new opportunities for neutral-atom quantum technologies.

Q 5.3 Mon 12:15 P 11

Rotational cooling of trapped molecular ions — •Monika Leibscher, Alexander Blech, and Christiane P. Koch — Dahlem Center for Complex Quantum Systems and Fachbereich Physik, Freie Universität Berlin, Germany

Polyatomic molecules are a promising new platform for fundamental physics and quantum information processing due to their rich internal structure. In particular, their rotational degrees of freedom span a large, well-isolated Hilbert space with strong anharmonicities, enabling precise control. Utilizing these features requires trapping and rotational cooling of molecules. We consider polar molecular ions which are co-trapped with atomic ions in a linear Paul trap. Dipole interaction couples molecular rotation to the collective vibration of the particles in the trap [1, 2]. We demonstrate that the complex rotational spectrum of asymmetric top molecules enables strong dipolar coupling that can be utilized for sympathetic sideband cooling of the rotational degrees of freedom [3]. Furthermore, by combining sideband cooling with coherent microwave control [4], we show that it is possible to tailor the rotational state distribution - either depleting arbitrary subspaces or cooling the entire manifold into a single rotational state.

[1] W. C. Campbell, E. R. Hudson, Phys. Rev. Lett. 125, 120501 (2020). [2] M. Leibscher, F. Schmidt-Kaler, Ch. P. Koch, arXiv:2504.00590 (2025). [3] M. Leibscher, Ch. P. Koch, arXiv:2506.20846 (2025). [4] M. Leibscher, E. Pozzoli, C. Perez, M.

Schnell, M. Sigalotti, U. Boscain and Ch . P. Koch, Commun. Phys. 5, 110 (2022).

Q 5.4 Mon 12:30 P 11

Λ-enhanced gray-molasses loading and EIT cooling of neutral atoms in nanophotonic traps — Lukas Pache, Antoine Glicenstein, Arno Rauschenbeutel, •Philipp Schneeweiss, Jürgen Volz, and Riccardo Pennetta — Department of Physics, Humboldt-Universität zu Berlin, 12489 Berlin, Germany

Nanophotonic waveguides enable the observation of strong interactions between guided photons and ensembles of laser-cooled atoms. However, nanophotonic traps for cold atoms typically have mode volumes $\ll \lambda^3$, far smaller than for free-space optical tweezers. This makes efficient loading of these traps challenging, thereby limiting the total number of waveguide-coupled atoms. Here, we implement Λ-enhanced gray-molasses (GM) in a nanofiber-based cold-atom setup and observe a 7-fold increase in the trap loading efficiency. We operate in an unconventional regime for GM cooling, given that our optical traps have a depth of only 22 μK. Despite this, we load more than 2000 atoms, achieving optical depths exceeding 100. After loading, using the GM beams, we perform efficient EIT-assisted cooling that is found to increase the trap storage time to 400(9) ms. This is a 5-fold improvement over the passive storage time. Remarkably, EIT-cooling also works with a single nanofiber-guided beam, requiring only about 100 pW of optical power. Our results provide an effective method to boost both the loading rate and the storage time of nanophotonic atom traps. Since GM employs blue-detuned light, they also offer a pathway to surpass the collisional blockade in nanophotonic traps and explore collective radiative phenomena such as selective radiance.

Q 5.5 Mon 12:45 P 11

Grey molasses cooling with grating magneto-optical traps — •Kai-Christian Bruns, Julian Lemburg, Joseph Muchovo, Vivek Chandra, Sam Ondráček, Hendrik Heine, and Ernst M. Rasel — Leibniz Universität Hannover, Institut für Quantenoptik

In the field of quantum sensing, cold atomic clouds are utilized as test masses in high-precision matter wave interferometers. They can be created using grating atom chips, which simplify and miniaturize quantum sensors by enabling the trapping of atoms in a grating magneto-optical trap with a single incident beam. This enhances the scalability and portability of quantum sensing devices and holds promise for a wide array of applications, from fundamental research to practical implementations in earth observation.

In this talk, we show sub-Doppler cooling results on the D_2 line of ^{87}Rb utilizing gray molasses cooling. We manage to cool the atoms to (830±100)nK and increase the phase-space density by a facor of three compared to conventional molasses cooling. The cooling performance surpasses state of the art gray molasses cooling experiments with ordinary six beam MOTs.

Q 6: Ultra-cold Plasmas and Rydberg Systems I (joint session A/Q)

Time: Monday 11:45–12:45 Location: N 1

Invited Talk Q 6.1 Mon 11:45 N 1

Experimental investigation of strongly interacting quantum fluids of light in rydberg atoms — •Amar Bellahsene, Tom Bienaimé, and Shannon Whitlock — Université de Strasbourg, CESQ-ISIS, Strasbourg, France

Photons are ideal quantum systems - easy to generate, manipulate, and detect - but their absence of mutual interactions limits their use for many-body physics and quantum simulation. A powerful approach to engineer strong and tunable photon-photon interactions is to propagate light through an ultracold atomic gas coupled to Rydberg states under electromagnetically induced transparency (EIT). This medium provides strong light-matter coupling and collectively enhanced nonlinearities, allowing photons to acquire an effective mass and interact, forming a platform for quantum fluids of light. My PhD work explores this regime using ultracold potassium 39 atoms in a Magneto-optical trap. We characterize how atomic nonlinear media mediate interactions between photons by measuring the Kerr nonlinearity in a two-level system and comparing it to the large enhancement achieved in a three-level Rydberg-EIT configuration. The nonlinear phase shifts are extracted with a Mach-Zehnder interferometer, providing a sensitive probe of interaction-induced optical response. By combining spatial structuring of the light field, strong Rydberg interactions, and interferometric detection, the goal is to demonstrate a quantum nonlinear medium where photons behave as interacting quasiparticles - opening the way toward the realization of a quantum fluid of light.

Q 6.2 Mon 12:15 N 1

Orientation of Trilobite Rydberg Molecules in Electric Fields — •Richard Blättner, Markus Exner, and Herwig Ott — RPTU Kaiserslautern-Landau

Rydberg molecules consist of a Rydberg atom bound to a ground state atom. The binding mechanism is based on the scattering interaction between the Rydberg electron and the ground state atom. Trilobite molecules are a subclass of high-l Rydberg molecules that exhibit a huge permanent electric dipole moment and are therefore highly sensible to electric fields. We report on the observation of trilobite molecules oriented by an electric field. We excite these molecules within a cloud of ultracold ^{87}Rb atoms using a three-photon excitation scheme. We make the molecules orientation visible on the 2D detector of a reaction microscope taking advantage of state changing collisions.

Q 6.3 Mon 12:30 N 1

Signatures of emerging kinetic constraints in a weakly interacting dissipative Rydberg gas — •Viktoria Noel[1] and Igor Lesanovsky[1,2] — [1]Institut für Theoretische Physik and Center for Integrated Quantum Science and Technology, Eberhard Karls Universität Tübingen, Auf der Morgenstelle 14, 72076 Tübingen, Germany — [2]School of Physics and Astronomy and center for the Mathematics and Theoretical Physics of Quantum Non-Equilibrium Systems, The University of Nottingham, Nottingham, NG7 2RD, United Kingdom

We investigate the relaxation dynamics of a weakly interacting, dissipative Rydberg gas, and identify subtle signatures typically associated with kinetic constraints in more strongly interacting settings. We access mesoscopic one- and two-dimensional systems and resolve the dynamical features underlying this behaviour using the truncated Wigner approximation, also supported by exact benchmarks on smaller systems. We observe a weak slowdown in temporal correlations relative to a simple relaxation, while spacetime snapshots show prolonged excitation patches signalling dynamical heterogeneity. We trace these features to the interplay of coherent driving, interactions, and dissipation, which in part restricts relaxation pathways. Our results highlight that the onset of kinetic constraints may occur before the strongly interacting regime is reached, establishing weakly interacting Rydberg arrays as a promising platform for studying emergent slowed dynamics out of equilibrium.

Q 7: Ultracold Matter II – Bosons (joint session Q/A)

Time: Monday 17:00–19:00 Location: P 2

Q 7.1 Mon 17:00 P 2

In-situ cooling of bosonic Mott insulators via reservoir engineering — •Michele Miotto, Francesco Petiziol, and André Eckardt — Institut für Physik und Astronomie, Technische Universität Berlin

The preparation of pristine Mott insulator (MI) states of ultracold atoms in optical lattices is a crucial resource for a wide range of quantum simulation experiments. Although these systems offer remarkable controllability, small fractions of excitations inevitably emerge during lattice loading, which can significantly affect experimental qual-

ity. This limitation highlights the need for new in-situ cooling techniques to purify imperfect MIs. In this work, we theoretically propose and analyze a reservoir-engineering scheme aimed at mitigating such excitations. Specifically, we investigate whether a portion of a two-dimensional lattice can act as an engineered bath for a smaller subsystem hosting the MI. Focusing on a bosonic MI at unit density, confined to a one-dimensional strip and characterized by doublon-holon impurities, we use numerical simulations to test whether tuning the bath parameters can induce irreversible absorption of these excitations, thereby stabilizing the MI toward a uniform density profile.

Q 7.2 Mon 17:15 P 2

Weakly interacting Bose gases in the canonical ensemble — •Jonata Santos[1], Axel Pelster[2], and Arnaldo Gammal[1] — [1]Universidade de São Paulo, Brazil — [2]University of Kaiserslautern-Landau, Germany

Based on the canonical description of a non-interacting Bose gas [1] we work out how both thermodynamic and statistical properties change perturbatively with respect to weak two-particle interactions. Up to first order we obtain a recursion formula for the canonical partition function, which consists of the same Feynman diagrams as the grand-canonical description [2] but with different Feynman rules. Resumming this recursion formula for the canonical partition function allows then to characterize the statistics of the ground-state occupancy by its respective cumulants. We demonstrate the applicability of this approach by analyzing a dilute Bose gas with contact interaction in a box trap. And we compare the results obtained by both periodic and Dirichlet boundary conditions in view of their relevance for current experiments with atomic gases, where the box trap is implemented, for instance, with digital mirror devices. [1] K. Glaum, H. Kleinert, and A. Pelster, Phys. Rev. A 06304 (2007). [2] A. Pelster and K. Glaum, Phys. Stat. Sol. B 237, 72 (2003).

Q 7.3 Mon 17:30 P 2

Dipolar supersolids in toroidal traps — •Paul Uerlings[1], Fiona Hellstern[1], Kevin Ng[1], Michael Wischert[1], Tim Jerglotz[1], Koushik Mukerjee[2], Malte Schubert[2], Stephan Welte[1,3], Ralf Klemt[1], Stephanie Reimann[2], and Tilman Pfau[1,3] — [1]5. Physikalisches Institut and Center for Integrated Quantum Science and Technology IQST, Universität Stuttgart — [2]Division of Mathematical Physics and NanoLund, LTH, Lund University — [3]CZS Center QPhoton

Supersolids formed from a dipolar BEC exhibit a spontaneous, periodic density modulation while maintaining the frictionless flow of a superfluid. This unique behavior results from breaking both the global U(1) gauge symmetry and the continuous translational symmetry, leading to three types of collective excitations: the first- and second-sound branches, along with amplitude (Higgs) modes. In harmonic traps, these Higgs-like excitations hybridize with other modes, making them difficult to observe experimentally. In this study, we theoretically investigate the excitation spectrum of a dipolar quantum gas of Dysprosium atoms confined in a toroidal trap. Our results reveal decoupled sound and amplitude-like modes. This allows us to study the time evolution and dispersion of a localized Higgs-like quasiparticle excitation. The quadratic dispersion of this quasiparticle, together with the periodic density modulation, leads to (fractional) revivals, similar to those observed in the optical Talbot effect. We also present our experimental work towards observing these excitations in-situ.

Q 7.4 Mon 17:45 P 2

Dynamic behaviour of density correlations across the chaotic phase for interacting bosons — •Óscar Dueñas Sánchez[1,2] and Alberto Rodríguez[1,2] — [1]Departamento de Física Fundamental, Universidad de Salamanca, E-37008 Salamanca, Spain — [2]Instituto Universitario de Física Fundamental y Matemáticas (IUFFyM), Universidad de Salamanca, E-37008 Salamanca, Spain

We study the dynamical manifestation of the chaotic phase in the time-dependent propagation of experimentally relevant two-particle correlations for one-dimensional interacting bosons. In particular, we show that the onset of chaos reshapes the correlation profiles, alters the propagation front and velocity, and modifies both the decay of the first correlation maximum and the long-time saturation values. These observables provide a detailed characterization of correlation transport beyond standard light-cone pictures. We further relate these findings to the emergence of a diffusive regime in the correlation propagation previously observed in Ref. [1], quantified through a suitably defined correlation transport distance.

[1] O. Dueñas, D. Peña and A. Rodríguez, Phys. Rev. Research 7, L012031 (2025)

Q 7.5 Mon 18:00 P 2

How to seed ergodic dynamics of interacting bosons under conditions of many-body quantum chaos — Lukas Pausch[1,2], Edoardo G. Carnio[3,4], Andreas Buchleitner[3,4], and •Alberto Rodríguez[5,6] — [1]Institut de Physique Nucléaire, Atomique et de Spectroscopie, CESAM, Université de Liège, B-4000 Liège, Belgium — [2]Present address: German Aerospace Center, Institute of Quantum Technologies, D-89081 Ulm, Germany — [3]Physikalisches Institut, Albert-Ludwigs-Universität Freiburg, Hermann-Herder-Straße 3, D-79104 Freiburg, Germany — [4]EUCOR Centre for Quantum Science and Quantum Computing, Albert-Ludwigs-Universität Freiburg, Hermann-Herder-Straße 3, D-79104 Freiburg, Germany — [5]Departamento de Física Fundamental, Universidad de Salamanca, E-37008 Salamanca, Spain — [6]Instituto Universitario de Física Fundamental y Matemáticas (IUFFyM), Universidad de Salamanca, E-37008 Salamanca, Spain

We demonstrate how the initial state of ultracold atoms in an optical lattice controls the emergence of ergodic dynamics as the underlying spectral structure is tuned into the quantum chaotic regime. Distinct initial states' chaos threshold values in terms of tunneling as compared to interaction strength are identified, as well as dynamical signatures of the chaos transition, on the level of experimentally accessible observables and time scales [1].

[1] L. Pausch, E. G. Carnio, A. Buchleitner, A. Rodríguez, Rep. Prog. Phys. 88(5), 057602 (2025).

Q 7.6 Mon 18:15 P 2

Vortex nucleation studied through spatially-resolved velocity fields — •Elinor Kath, Jelte Duchene, Hanyi Jang, Helmut Strobel, and Markus K. Oberthaler — Kirchhoff-Institut für Physik, Universität Heidelberg

We developed a method to measure spatially resolved superfluid velocity fields from a single experimental realisation. This technique grants direct access to dynamical properties that remain hidden in density images, like phase gradients, transport mechanisms, and turbulent flow patterns.

The nucleation of vortices is associated with a rise in incompressible kinetic energy, drawn from the kinetic energy's compressible, phononic part. By extracting velocity fields we obtain the full kinetic energy and separate its compressible (phononic) and incompressible (vortical) components. This allows us to study the conversion of compressible to incompressible energy during vortex nucleation.

We create a vortex gas by strongly distorting the condensate's phase and density. We track the appearance of vortices in time through density depletions, the curl of the velocity field, and the evolving energy balance, making a first step towards the study of how quantized vortices first form in quantum fluids, how turbulence initiates, how different excitations redistribute energy.

Q 7.7 Mon 18:30 P 2

Observation of sine-Gordon solitons in a spinor Bose-Einstein condensate — Yannick Deller, Alexander Schmutz, Raphael Schäfer, •Alexander Flamm, Florian Schmitt, Ido Siovitz, Thomas Gasenzer, Helmut Strobel, and Markus Oberthaler — Kirchhoff-Institut für Physik, Universität Heidelberg, Heidelberg, Germany

Sine-Gordon solitons are a paradigmatic solution of the integrable sine-Gordon model. Utilizing a robust and reproducible local spinor phase imprinting scheme, we are able to produce sine-Gordon solitons in a quasi one-dimensional spin-1 BEC. We report on their time evolution while tuning their velocity by using the effective quadratic Zeeman shift, and therefore observe the characteristic collision behavior of the integrable sine-Gordon model. These results confirm that spinor BECs are a highly controllable experimental platform for studying the dynamics of the sine-Gordon model and its generalizations.

Q 7.8 Mon 18:45 P 2

Single Realization Spatially Resolved Velocity Reconstruction for a 2D BEC — •Jelte Duchene, Elinor Kath, Hanyi Jang, Helmut Strobel, and Markus Oberthaler — Kirchhoff-Institut für Physik, Universität Heidelberg

We present a method to extract both the velocity field and density of a 2D Bose-Einstein condensate (BEC) from single realizations. The method is based on Bragg spectroscopy extended to two dimensions, where two pairs counter propagating laser pulses with frequencies ω and $\omega + \delta$ are incident on the atomic cloud and resonant with atoms according to their initial velocity. By imaging the scattered atoms after a short time of flight and modelling the Bragg beams as coupled two-level systems, we can reconstruct the spatially resolved velocity along the beam direction. A second pair of Bragg beams along a different axis allows us to extract the full 2D velocity field. Short Bragg pulses with a broad bandwidth address a broad band of velocities to enable the reconstruction of the full velocity field from a single realization of the BEC. We characterize the method by measuring the velocity profile of a single vortex and collective excitation of the system. This technique opens a path toward single-shot studies of 2D superfluid dynamics like the propagation of excitations, quantum turbulence, and vortex dynamics.

Q 8: Nanophotonics and Integrated Photonics II

Time: Monday 17:00–19:00 Location: P 3

Invited Talk Q 8.1 Mon 17:00 P 3

Heterogeneous Quantum Photonics: A Platform for Quantum Sensing, Networking, and Transduction — •Samuel Gyger — Saarland University, Saarbrücken, Germany — Stanford University, Stanford, United States

Realizing quantum photonic technologies requires architectures beyond commercial foundry processes. While they provide reliability and favorable cost reduction for high-volume production, their rigid processes often conflict with the high-mix environment of quantum research, and they typically lack integrated quantum hardware, such as single photon detectors (SNSPDs) or quantum light sources. We propose a "chiplet-based" approach using heterogeneous integration of optimized submodules and robotic automation to bring industrial-grade consistency to the research lab.

We show that robotic resist development reduces the inter-chip resistance spread in superconducting devices from $\approx 7\%$ to $\approx 2\%$. We also demonstrate deterministic SNSPD integration onto arbitrary photonic substrates via transfer printing. Finally, co-integrated lithium niobate and silicon optomechanical crystals enable a platform for quantum transduction. We improve thermal anchoring to achieve ground-state operation with pulsed sideband asymmetry at repetition rates up to 3 MHz.

This automated, heterogeneous framework provides a scalable path for next-generation quantum technology laboratories.

Q 8.2 Mon 17:30 P 3

On-chip wavefront shaping via transverse mode control in integrated Si_3N_4 multimode waveguides — •Stefan Rothe, Ekin B. Boşdurmaz, Leonie M. van der Heide, Redlef B. G. Braamhaar, Jeroen P. Korterik, and Pepijn W. H. Pinkse — MESA+ Institute, University of Twente, PO Box 217, 7500 AE Enschede, The Netherlands

We demonstrate spatial mode control in integrated Si_3N_4 multimode waveguides (MWGs), establishing a compact and robust platform for wavefront shaping. We fabricate the Si_3N_4 MWGs on silicon wafers using standard low-loss nanophotonic processes in the MESA+ Nanolab Cleanroom. By adjusting the relative phases of guided transverse modes, we can generate arbitrary output fields like diffraction-limited foci, or any other modal superposition, directly at the chip output facet. One spatial light modulator placed in the conjugate plane of the MWG input enables to coherently excite and control up to five transverse modes. We apply a step-sequential optimization algorithm, and concentrate 76% of the output intensity into a diffraction-limited focus, approaching the $\pi/4$-limit for phase-only wavefront shaping. This demonstrates, for the first time, reconfigurable multimode phase control within an integrated Si_3N_4 platform. Our approach outlines the way for fully integrated spatial light control. Future integration of thermo-optic phase shifters will eliminate bulky free-space optics and enable in-waveguide modulation for scalable multimode quantum networks and photonic computing architectures.

Q 8.3 Mon 17:45 P 3

Micro-structuring of electrically switchable PEDOT:PSS using one-photon polymerization — •Julian Bolsinger, Dominik Ludescher, Leander Siegle, Monika Ubl, and Harald Giessen — 4th Physics Institute and Research Center SCoPE, University of Stuttgart, Pfaffenwaldring 57, 70569 Stuttgart, Germany

PEDOT:PSS is a conductive polymer with excellent electrical, optical, and mechanical properties used for transparent electrodes, biocompatible electronics, and sensor technology. Fabrication often requires precise structuring of a thin polymer film, typically achieved through inkjet printing, electron-beam lithography, or femtosecond direct laser writing. However, these methods are costly or offer limited resolution. We present two methods for structuring PEDOT:PSS based on one-photon polymerization using incoherent ultraviolet or coherent near-infrared light. In the first, a spin-coated PEDOT:PSS sample is exposed to ultraviolet light through a photomask, inducing cross-linking of polymer chains in the illuminated regions. Our method provides an inexpensive way for patterning large areas. For the second technique, a continuous-wave near-infrared laser beam is focused onto the polymer layer while the sample is translated, offering great flexibility and cost efficiency. We realize electrically switchable patterns with micrometer spatial resolution while keeping the polymer stable and conductive. In combination with 3D-printed micro-optics, PEDOT:PSS enables dynamic functionality. We are working towards integrating micro-optics with electrically switchable structures such as apertures and diffraction gratings.

Q 8.4 Mon 18:00 P 3

Macroscopic monolayer WS2 for robust room-temperature exciton-polaritons in open cavities — •Sander Scheel[1], Shiyu Huang[1], Jiang Qu[2], Johannes Düreth[1], Dominik Horneber[1], Simon Widmann[1], Monika Emmerling[1], Martin Kamp[1], Simon Betzold[1], Sven Höfling[1], and Sebastian Klembt[1] — [1]Technische Physik, Wilhelm-Conrad-Röntgen-Research Center for Complex Material Systems, and Würzburg-Dresden Cluster of Excellence ct.qmat, University of Würzburg, Germany — [2]Leibniz-Institute for Solid State and Materials Research Dresden

Combining two-dimensional materials with photonic lattices offers a powerful route toward tunable exciton-polariton devices using engineered band structures, yet progress has been limited by the poor reproducibility of conventional exfoliation methods. Here, we demonstrate large-area monolayer WS_2 with high optical uniformity using Au-assisted exfoliation and 1-dodecanol encapsulation, providing a scalable platform for exciton-polariton studies. Room-temperature strong coupling with a Rabi splitting of 31 meV is achieved in open microcavities, yielding polaritonic spectra consistent with literature while eliminating sample-to-sample variability. Implementing a kagome photonic lattice enables the realization of polariton band structures, including Dirac cones and flat bands. These results establish large-area monolayer semiconductors as a robust basis for controllable polaritonic lattices at room-temperature.

Q 8.5 Mon 18:15 P 3

Feibelman parameters from jellium models for a metal surface — •Carsten Henkel — Universität Potsdam, Institut für Physik und Astronomie

In nano-photonics, we currently witness a revived interest in quantum models for the surface of a metal, going beyond a sharp, macroscopic interface between two media with local conductivities [1]. Multiple physical features coexist: the atomic lattice structure (crystalline, reconstructed or amorphous) [1], the smooth onset of the electron density [2], the creation of electron-hole pairs [4] and of collective longitudinal excitations like (surface) plasmons [5]. We revisit 100 years of jellium models starting from hydrodynamics with simple exchange-correlation potentials. The aim is to capture the optical response of the surface in terms of few additional Feibelman parameters related to the oscillating near-surface charge [6].

[1] C. Ciracì and F. Della Sala, Phys. Rev. B 93 (2016) 205405; N. Asger Mortensen & al, Nanophotonics 10 (2021) 3647
[2] R. Smoluchowski, Phys. Rev. 60 (1941) 661
[3] J. Frenkel, Z. Physik 51 (1928) 232
[4] I. Tamm and S. Schubin, Z. Phys. 68 (1931) 97

[5] D. Wagner, Z. Naturforsch. A 21 (1966) 634; G. Mukhopadhyay and S. Lundqvist, Physica Scr. 17 (1978) 69
[6] J. Harris and A. Griffin Phys. Lett. A 34 (1971) 51; K. Kempa and W. L. Schaich, Phys. Rev. B 34 (1986) 547; Peter J. Feibelman, Phys. Rev. B 40 (1989) 2752

Q 8.6 Mon 18:30 P 3

Deep Learning Based Inverse Design of Nanophotonic Devices — •David Lemli[1,2,3], Marco Butz[1,2,3], Marlon Becker[4], Benjamin Risse[4], and Carsten Schuck[1,2,3] — [1]Department for Quantum Technology, University of Münster, Heisenbergstr. 11, 48149 Münster, Germany — [2]Center for Soft Nanoscience, Busso-Peus-Str. 10, 48149 Münster, Germany — [3]Center for Nanotechnology, Heisenbergstr. 11, 48149 Münster, Germany — [4]Department for Geoinformatics, University of Münster, Heisenbergstr. 2, 48149 Münster, Germany

Photonic integrated circuits constitute a key platform for all areas of quantum technology, driving the need for nanophotonic components that achieve high optical performance while adhering to fabrication constraints such as minimum feature sizes.

Topology optimization provides a powerful framework for designing highly efficient, compact, and multifunctional photonic devices. Here, we present Memory Metropolis (MeMe), a deep-learning enhanced discrete topology optimization algorithm that employs deep template networks, a novel neural network architecture for generating proposal distributions in simulated annealing. By promoting the clustering of individual pixels, MeMe produces device geometries compatible with state-of-the-art lithographic processes. We experimentally validate the performance of optimized devices on the emerging tantala-on-insulator platform. Fabrication compatibility naturally emerges from MeMe's optimization process, representing a key algorithmic innovation in discrete inverse design.

Q 8.7 Mon 18:45 P 3

Imaging of Nanoholes with Digital Holography — •Lukas Limmer[1], Abhishek Anand[2], Wladimir Schoch[2], Ulrich Rädel[3], Johannes Hecker Denschlag[2], and Harald Giessen[1] — [1]4th Physics Institute, University of Stuttgart, Germany — [2]Institute for Quantum Matter, University of Ulm, Germany — [3]Frauenhofer IOF, Jena, Germany

We experimentally investigate a recently proposed low photon number method for photographing nanohole grid patterns on a two-dimensional opaque phase mask with digital holography. The experimental setup back-illuminates the phase mask with a weak coherent light source and imprints the phase information of the nanoholes diffraction pattern on a strong coherent reference beam on a CCD-camera chip. First measurements suggest that a reconstruction of the original hole pattern is possible for less than 100 scattered photons per hole. This shows potential for imaging ultra-cold atoms in optical lattices.

Q 9: Open Quantum Systems and Spin-Boson Systems I

Time: Monday 17:00–18:45 Location: P 4

Q 9.1 Mon 17:00 P 4

Hierarchical time translational symmetry breaking — •Jan Carlo Schumann[1], Igor Lesanovsky[1,2], and Parvinder Solanki[1] — [1]Institute for Theoretical Physics, University of Tübingen, Germany — [2]School of Physics and Astronomy, University of Nottingham, United Kingdom

Spontaneous symmetry breaking is one of the central organizing principles in physics. Recently, time crystals have emerged as a new phase of matter, spontaneously breaking the time translational symmetry. Depending on the nature of symmetry breaking, they are mainly categorized as discrete (DTC) or continuous (CTC) time crystals. While CTCs and DTCs have been explored independently, the potential effects emerging from their mutual interaction remain unexplored. In this work, we demonstrate that hierarchical time-translational symmetry breaking (HSB) stems from the interaction of a DTC and a CTC, which we term *hierarchical time crystals*. The HSB phenomenon unfolds in two steps. First, the CTC spontaneously breaks the continuous time translational symmetry of the system's dynamical generator. The emerging time-periodicity of the CTC can then, in turn, be broken discretely by the DTC, manifesting in a sub-harmonic response to the CTC phase. Interestingly, the DTC breaks a symmetry that does not even exist for the generator of the dynamics, leading to a convoluted non-equilibrium phase of matter in time. We demonstrate that the novel HSB phenomenon is robust, emerging for fundamentally different coupling schemes and persisting across wide ranges of system parameters, thereby confirming the stable many-body phase.

Q 9.2 Mon 17:15 P 4

Non-classical features in vibrational states under electronic strong coupling — •Réka Schwengelbeck, Maxence Pandini, Ruben Daraban, and Johannes Schachenmayer — CESQ/ISIS (UMR 7006), CNRS and Université de Strasbourg, 67000 Strasbourg, France

We analyze vibrational dynamics in a toy-model setup for polaritonic chemistry under collective electronic strong coupling with many molecules. In a Holstein-Tavis-Cummings model, incoherently excited by a photon, we show that disorder leads to non-Gaussian states of vibrational modes on short time scales at the single-molecule level. Using exact matrix product state simulations, we demonstrate that this effect can remain robust for larger molecule numbers and cannot be effectively described with thermal states. Furthermore, we compare simulations of the exact quantum dynamics with semi-classical approximations. We find that the Ehrenfest approximation can reproduce only ensemble-averaged observables in the thermodynamic limit. Simulations in the truncated Wigner approximation can qualitatively produce some asymmetric features of vibrational Wigner functions, but fail to capture the non-Gaussian effects quantitatively. Our work highlights the importance of disorder and genuine quantum effects in understanding cavity-modified nuclear dynamics in polaritonic chemistry at the microscopic level.

Q 9.3 Mon 17:30 P 4

Interplay of collective radiance and particle statistics in quantum degenerate gases — •Julian Lyne[1,2], Nico Bassler[3], Kai Phillip Schmidt[2], and Claudiu Genes[3,1] — [1]Max Planck Institute for the Science of Light, Staudtstraße 2, 91058 Erlangen, Germany — [2]Friedrich-Alexander-Universität Erlangen-Nürnberg, Staudtstraße 7, 91058 Erlangen, Germany — [3]Technische Universität Darmstadt, Hochschulstraße 4, 64289 Darmstadt

We investigate the interplay of collective radiance and particle statistics in a dual-species quantum degenerate gas in a harmonic trap, where the two species correspond to the electronic ground and excited states of a bosonic or fermionic two-level system. The dissipative dynamics are modeled by a Lindblad master equation quartic in the field operators, which conserves the total particle number. We show how Dicke superradiance and variants thereof emerge in this description. Further, we show how the effects of particle statistics diminish at finite temperature and finite density, and the dynamics of distinguishable particles emerge.

Q 9.4 Mon 17:45 P 4

Non-Equilibrium Dynamics and Metastable Behavior in Strongly Coupled Atom-Light Systems — •Simon Balthasar Jäger[1], Ameneh Sheikhan[1], Catalin-Mihai Halati[2], Luisa Tolle[1], and Corinna Kollath[1] — [1]Physikalisches Institut, University of Bonn — [2]Max Planck Institute for the Physics of Complex Systems, Dresden

We investigate the open quantum dynamics of interacting bosonic atoms described by the Bose-Hubbard model under strong light-matter coupling. In the slow-tunneling regime, we derive an effective rate equation for the bosonic Fock states that accurately captures the long-time atomic dynamics. This framework enables numerically efficient simulations and uncovers pronounced metastable behavior, including long-lived transients and bistable atom-light configurations. By comparing the stationary state to thermal ensembles, we identify parallels and deviations arising from interatomic interactions and dissipative light-matter coupling. Our results reveal non-equilibrium phenomena generated by the interplay of strong interactions and dissipation in open quantum systems.

Q 9.5 Mon 18:00 P 4

Identifying the limitations of the Born-Markov approximation in spin-phonon bath system — •Mohamed Belhassen[1], Gregor Pieplow[1], and Tim Schröder[1,2] — [1]Humboldt-Universität zu Berlin, Berlin, Germany — [2]Ferdinand-Braun-Institut, Berlin, Germany

Diamond color centers are a promising platform for quantum information processing. In particular, we focus on group-IV vacancies as candidates for implementing long-lived quantum memories. To better understand phonon-induced decoherence, we study the quantum master equation of the system including spin-phonon interactions at finite temperature. Due to the complexity of this problem, this equation is typically derived under the Born-Markov approximation. However, this approximation leads to a significant discrepancy between theoretically predicted and experimentally measured coherence times. In this work, we aim to improve the theoretical prediction by analyzing the validity of the Born-Markov approximation and comparing it with non-Markovian approaches.

Q 9.6 Mon 18:15 P 4

Spontaneous emission dynamics in topological quantum emitter chains — •Jonathan Sturm and Adriana Pálffy — Julius-Maximilians-Universität Würzburg

Quantum emitter arrays are a powerful platform enabling tailored control of quantum optical phenomena, like super- and subradiance or efficient photon storage. Since state-of-the-art experimental techniques allow the realization of almost arbitrary lattice structures, a natural question is what physical effects arise if the lattice has nontrivial topology.

We theoretically study the spontaneous emission dynamics in quantum emitter chains with Su-Schrieffer-Heeger geometry similar to the ones studied in [1]. By solving the quantum master equation, we investigate how the presence of protected edge modes can be utilized to enhance the properties of the emitted light. Our studies pave the way for optimized single-photon sources [2] and topologically protected mirrorless lasing [3].

[1] J. Sturm and A. Pálffy, Phys. Rev. Research **7**, L032069 (2025)

[2] Y. Wang *et al.*, npj Quantum Inf **10**, 13 (2024)

[3] A. Bychek *et al.*, Phys. Rev. Lett. **135**, 143601 (2025)

Q 9.7 Mon 18:30 P 4

Observing time-dependent energy level renormalization in an ultrastrongly coupled open system — •Florian Hasse, Frederike Doerr, Tobias Spanke, Deviprasath Palani, Ulrich Warring, Alessandra Colla, Heinz-Peter Breuer, and Tobias Schaetz — Institute of Physics, University of Freiburg, Hermann-Herder-Str. 3, 79104 Freiburg, Germany

Understanding how strong coupling and memory effects influence energy levels in open quantum systems is a fundamental challenge. Here, we experimentally probe these effects in a two-level open system coupled to a single-mode quantum environment, using Ramsey interferometry in a trapped ion. Operating in the strong coupling regime, we observe both dissipative effects and time-dependent energy shifts of up to 15% of the bare system frequency, with the total system effectively isolated from external environments [1]. These dynamic shifts, likely ubiquitous across quantum platforms, arise solely from ultra-strong system-mode interactions and correlation build-up and are accurately predicted by the minimal-dissipation Ansatz [2]. Our approach identifies these as generalised Lamb shifts, matching conventional predictions on time-average. We provide experimental fingerprints supporting the Ansatz of minimal-dissipation, thereby suggesting it as a testable quantum thermodynamics framework and establishing a foundation for future benchmarks in strong-coupling quantum thermodynamics and related technologies.

[1] Colla, A., Hasse, F., et al., Nat. Commun. 16, 2502 (2025).
[2] Colla, A. and Breuer, H.-P., Phys. Rev. A 105, 052216 (2022)

Q 10: Quantum Technologies – Photon Detectors and Sources

Time: Monday 17:00–19:00 Location: P 5

Q 10.1 Mon 17:00 P 5

Photon-number resolved characterization of a type-II SPDC light source — •Umair A. Mir[1,2], Oskar Kohout[1,2], Carlos Sevilla[1,2], and Fabian Steinlechner[1,2] — [1]Institute of Applied Physics IAP, Friedrich Schiller University, Jena, Germany — [2]Fraunhofer Institute of Applied Optics and Precision Engineering IOF, Jena, Germany

Squeezed light sources have become important resources for applications in quantum information processing areas. Spontaneous parametric down conversion (SPDC) is the most widely used method to generate squeezed states of light. In a type-II SPDC process, the signal and idler photons are orthogonally polarized, and when they are of the same wavelength, the output state corresponds to a two-mode squeezed vacuum (TMSV) state. The signal and idler modes are then perfectly correlated and entangled in the photon-number basis, which can be directly probed via joint photon statistics (JPS) measurements using a photon-number-resolving (PNR) detector. In this work, we measure JPS of type-II apktp and ppktp crystals serving as SPDC sources using a commercially available PNR detector with up to four photon resolution. From the measured statistics, we estimate the overall squeezing gain and transmission losses via a loss model that minimizes the deviation between simulated and experimental JPS, providing an alternative characterization method to conventional homodyne detection. Furthermore, we discuss how JPS measurements can offer insights into the spectral composition of more general SPDC-generated light, where each spectral mode corresponds to an independent TMSV state.

Q 10.2 Mon 17:15 P 5

Spectro-Temporal Study of Photon Pairs from a Lithium Niobate Waveguide Resonator — •Stefan Kazmaier and Kaisa Laiho — Deutsches Zentrum für Luft- und Raumfahrt (DLR), Institut für Quantentechnologien, Wilhelm-Runge-Straße 10, 89081 Ulm

Lithium niobate is one of the most widely used platforms for generating photon pairs, usually called signal and idler, via parametric down-conversion (PDC). Here we characterize a commercially available type-II periodically-poled lithium niobate waveguide (PPLN-WG) with highly reflecting end-facets forming a resonator at the PDC wavelengths. We measure conventional key figures of merit of our PDC source, including the coincidence-to-accidentals ratio (CAR), Klyshko efficiencies, and the temporal profile of signal and idler. Furthermore, by independently measuring the optical path length difference of signal and idler, we additionally extract the phasematching bandwidth, the group delay, and the resonators cluster spacing [1]. These results provide a comprehensive performance assessment of the device and support its use in quantum optics and integrated photonics applications.

[1] Kazmaier and Laiho, Phys. Scr. 100, 081502 (2025).

Q 10.3 Mon 17:30 P 5

Extracting pairs of time-bin entangled photons from resonance fluorescence — •Xinxin Hu, Gabriele Maron, Luke Masters, Arno Rauschenbeutel, and Jürgen Volz — Department of Physics, Humboldt Universität zu Berlin, 10099 Berlin, Germany

Photon-photon entanglement and photon antibunching are fundamental manifestations of the quantum nature of optical light fields, but are typically regarded as distinct phenomena. Here, we experimentally demonstrate that pairs of narrow-band time-bin entangled photons can be naturally extracted from resonance fluorescence. We split the collected fluorescence of a single trapped atom on a 50:50 beamsplitter, resulting in strong temporal correlations between photons at the beamsplitter outputs. A time-bin coincidence between the two output modes then projects their state onto a maximally entangled Bell state. This entanglement is evidenced by violating the CHSH-Bell inequality as well as by reconstructing the density matrix of the photon pair. Importantly, we show that the entanglement persists both for weak and strong excitation of the emitter. Our results establish resonance fluorescence as an efficient source of time-bin entangled photon pairs, i.e., a practical and scalable resource for quantum communication and photonic quantum technologies.

Q 10.4 Mon 17:45 P 5

Deterministic single ion implantation of Er into thin film lithium niobate — •Maranatha Andalis, Reiner Schneider, and Klaus D. Jöns — Institute for Photonic Quantum Systems (PhoQS), Center for Optoelectronics and Photonics Paderborn (CeOPP) and Department of Physics, Paderborn University, 33098 Paderborn, Germany

Incorporating rare-earth ions (REIs) into lithium niobate-on-insulator (LNOI) is of great interest for scalable photonic integrated circuits (PICs), as it enhances the functionality of LNOI with the unique properties offered by REIs. Erbium ions can be introduced into LNOI through ion implantation, enabling device operation at telecom wavelengths. In our setup, the ion implanter achieves an 85% implantation efficiency using secondary electron emission detection for single ion Er implantation into LNOI. The results presented here provide an overview of the most recent advancements in this topic.

Q 10.5 Mon 18:00 P 5

Narrowband frequency-entangled photon source based on a whispering gallery resonator — •Yen-Ju Chen[1,2], Sheng-Hsuan Huang[1,2], Thomas Dirmeier[1,2], Kaisa Laiho[3], Dmitry V. Strekalov[2], Andrea Aiello[2], Gerd Leuchs[1,2], and Christoph Marquardt[2,1] — [1]Chair of Optical Quantum Technologies, Friedrich-Alexander-Universität Erlangen-Nürnberg, Staudtstrasse 7/A3, 91058, Erlangen, Germany — [2]Max Planck Institute for the Science of Light, Staudtstrasse 2, 91058 Erlangen, Germany — [3]German Aerospace Center (DLR e.V.), Institute of Quantum Technologies, Wihelm-Runge-Str. 10, 89081, Ulm, Germany

Frequency-entangled photons have emerged as a powerful tool for advancing quantum technologies, such as sensing. While the generation of highly-nondegenerate frequency-entangled photons have been achieved using non-resonant parametric down-conversion (PDC), the realization of narrowband frequency-entangled states remains an experimental challenge due to the complexity associated with the optical cavity design and control. In this work, we report the realization of a highly-nondegenerate frequency-entangled photon source based on resonant PDC in a whispering gallery resonator (WGR). This approach overcomes existing limitations by leveraging total internal reflection within spherical geometries. Moreover, this WGR device facilitates the generation of a high-brightness photon source, further enhancing its use for quantum applications.

Q 10.6 Mon 18:15 P 5

Synchronizing the generation of SPDC photons with a storage loop — •Xavier Barcons Planas[1,2], Helen M. Chrzanowski[2], Siavash Qodratipour[2], Fuad Haddad[1,3], Zora Kutz[1,3], and Janik Wolters[1,3,4,5] — [1]German Aerospace Center, Berlin, Germany — [2]Humboldt-Universität zu Berlin, Berlin, Germany — [3]Technische Universität Berlin, Berlin, Germany — [4]Einstein Center Digital Future, Berlin, Germany — [5]AQLS UG (haftungsbeschränkt), Berlin, Germany

Heralded spontaneous parametric down-conversion (SPDC) is one of the most mature techniques for producing pure single photons. Despite the probabilistic nature of SPDC photon-pair generation, parallelization of photon creation events through multiplexing can boost the probability of photon generation [1]. In the temporal degree of freedom, a switchable loop storage cavity has been studied [2,3]. Here, we present a monolithic cavity heralded SPDC single-photon source [4] and demonstrate time-multiplexed photon synchronization using a fiber optical storage loop. The achieved low loop roundtrip loss (<12%) and synchronization across 20 time bins result in substantial enhancements in the n-photon synchronized rates, while the multiphoton contamination increases only slightly. This approach is therefore promising for photonic quantum information processing.

[1] E. Meyer-Scott et al., Rev. Sci. Instrum. **91**, 041101 (2020)
[2] T. Pittman et al., Phys. Rev. A **66**, 042303 (2002)
[3] F. Kaneda et al., Optica **2**, 1010 (2015)
[4] X. B. Planas et al., (in preparation)

Q 10.7 Mon 18:30 P 5

Reducing Dark Counts in SNSPDs through Optical Shielding Designs and an On-Chip SiN Polarisation Beam Splitter within the MultiQomm Project — •César Bertoni Ocampo[1,2,3], Connor A. Graham-Scott[1,2,3], Janis Averbeck[1,2,3], and Carsten Schuck[1,2,3] — [1]Department for Quantum Technology, University of Münster — [2]Center for NanoTechnology - CeNTech, Münster — [3]Center for Soft Nanoscience - SoN, Münster

Photonic integrated circuits (PIC) hold great potential for realizing scalable architectures for future quantum networks, as they allow for realizing single-photon counting, routing and state discrimination on reproducible chips. However, low-noise detection and polarization management present important practical challenges on otherwise well established nanophotonic platforms, such as silicon nitride (SiN) on insulator. Here we report on the integration of superconducting nanowire single photon detectors (SNSPDs) with SiN-waveguides that approach < 1 cps dark count rate through locally shielding dedicated areas of a PIC. Moreover, we develop nanophotonic devices that allow for distinguishing transverse electric and magnetic polarization with > 15 dB extinction ratio and straightforwardly integrate with SNSPDs and polarization-agnostic 3D-printed fiber-chip interfaces. Making polarization sensitive nanophotonic functionalities and single photon detectors with low dark count rate available on SiN-PICs enables novel realizations of quantum key distribution receivers and quantum communication systems.

Q 10.8 Mon 18:45 P 5

Generation of polarization-entangled Bell states in monolithic photonic waveguides by leveraging intrinsic crystal properties — Trevor Vrckovnik[1,2], Dennis Arslan[1], Falk Eilenberger[1,2], and •Sebastian Schmitt[1,2] — [1]Fraunhofer Institute for Applied Optics and Precision Engineering IOF, Albert-Einstein-Str. 7, 07745 Jena, Germany — [2]Institute of Applied Physics, Abbe Center of Photonics, Friedrich Schiller University Jena, Albert-Einstein-Str. 15, 07745 Jena, Germany

Advanced photonic quantum technologies-from quantum key distribution to quantum computing-require on-chip sources of entangled photons that are both efficient and scalable. This theoretical study demonstrates the generation of polarization-entangled Bell states in structurally simple waveguides by exploiting intrinsic nonlinear-crystal properties, eliminating the need for elaborate phase-matching schemes based on spatial modulation. We derive general criteria for the second-order susceptibility tensor that enable cross-polarized photon-pair generation via spontaneous parametric down-conversion in single-material waveguides and categorize all birefringent, non-centrosymmetric crystal classes accordingly. Using coupled-mode theory, we numerically analyze cuboid waveguides made from lithium niobate and barium titanate. Barium titanate consistently outperforms lithium niobate, offering higher nonlinear efficiency and high concurrence over a much broader spectral range. These findings outline a practical path toward efficient, fabrication-friendly, and scalable sources of polarization-entangled photons for integrated quantum photonic circuits.

Q 11: QuanTour I – Single Photons & Foundations

Inspired by QuanTour, the traveling quantum-dot light source, the sessions QuanTour I-V focus on the physics of quantum light generation in solid-state systems and applications in quantum networks.

Time: Monday 17:00–19:00 Location: P 7

Q 11.1 Mon 17:00 P 7

QuanTour - Combining excellence in Research and Science Communication — •Doris Reiter[1] and Tobias Heindel[2] — [1]Condensed Matter Theory, TU Dortmund University, Germany — [2]Department of Quantum Technology, University of Münster, Germany

QuanTour is the unique journey of a quantum emitter across Europe and the World. Since April 2024, this globe-trotting quantum emitter has been connecting researchers and the public through a collaborative scientific and outreach initiative. At each stop, the single-photon purity of the same emitter was characterized via Hanbury Brown and Twiss correlation measurements. We compare the results obtained in the European labs and discuss its relevance for the standardization of measurements in quantum technologies. In addition, we summarize the outreach activities associated with QuanTour, discussing their reach and impact. This collaborative effort demonstrates how scientific networks can be leveraged for effective and innovative science communication.

Q 11.2 Mon 17:15 P 7

QuanTour at PTB: a metrologist‘s perspective — •Hristina Georgieva[1], Lisa Quack[1], Marco López[1], Stefan Kück[1], Lucas Rickert[2], Doris Reiter[3], and Tobias Heindel[4] — [1]Physikalisch-Technische Bundesanstalt, Braunschweig, Germany — [2]Technische Universität Berlin, Berlin, Germany — [3]Technische Universität Dortmund, Dortmund, Germany — [4]Department für Quantentechnologie, Universität Münster, Münster, Germany

QuanTour is an outreach project in which a quantum emitter is sent to different universities and research institutions worldwide, enabling comparative measurements on the same chip. We present the results obtained at PTB. We measured the emission spectrum, the decay time and the excitation-power-dependent $g^{(2)}(0)$ value of the single-photon emitter based on a quantum dot in a circular Bragg grating. The core of our self-built confocal microscope is a set of high-transmission spectral filters. In contrast to the common use of a monochromator for the spectral filtering, this approach provides high count rates at the single-photon detector, while maintaining a low multiphoton probability. Moreover, consistent with observations from other project partners, we measured a tenfold improvement of the $g^{(2)}(0)$ under p-shell excitation compared with non-resonant excitation. This combination of high photon flux and low $g^{(2)}(0)$ is particularly relevant for the calibration of single-photon detectors. In addition, the demonstrated robustness and durability of the quantum emitter throughout the project is highly valuable for ensuring reliable and reproducible measurements in the field of quantum metrology.

Invited Talk Q 11.3 Mon 17:30 P 7

Quantum radiometry metrology for quantum photonics technologies — •Angela Gamouras[1], Malcolm White[2], Nathan Tomlin[3], Michelle Stephens[3], John Lehman[3], Philip Poole[1], Dan Dalacu[1], and Robin Williams[1] — [1]National Research Council Canada, Ottawa, Canada — [2]University of Colorado Boulder, Boulder, USA — [3]National Institute of Standards and Technology, Boulder, USA

Quantum photonics technologies are transitioning from research prototypes to widely adopted tools in laboratories and industry. Quantum photonic integrated circuits - devices that combine single-photon sources, detectors, and other components on a single chip - are now integral to quantum networking and computing hardware. Accurate characterization of single-photon sources and single-photon detector efficiencies are essential for verifying and validating system performance. However, these measurements remain a persistent challenge. Current characterization methods typically rely on standard optical power meters and attenuated laser sources to calibrate detector efficiency. In this presentation, we introduce quantum radiometry techniques designed to meet the demands of quantum photonics systems. We describe an ultra sensitive radiometer chip capable of measuring the optical power emitted by a quantum dot single-photon source. This approach enables direct source characterization, which can be extended to assess on chip components. Our measurement technique shows the feasibility of implementing optical power metrology for quantum dot emitters, enabling the validation and testing of quantum photonic technologies.

Q 11.4 Mon 18:00 P 7

Advances in Quantum Light Generation for Quantum Communication at Telecom Wavelengths — •Robert Behrends[1], Lucas Rickert[1], Pratim K. Saha[1], Mareike Lach[1], Martin v. Helversen[1], Nils D. Kewitz[1], David Becker[1], Jochen Kaupp[2], Yorick Reum[2], Tobias Huber-Loyola[2], Sven Höfling[2], Andreas Pfenning[2], and Tobias Heindel[3] — [1]Institute of Physics and Astronomy, Technical University Berlin, Hardenbergstraße 36, 10623 Berlin, Germany — [2]Technische Physik, Physikalisches Institut and Würzburg-Dresden Cluster of Excellence ct.qmat, Universität Würzburg, Am Hubland, 97074 Würzburg, Germany — [3]Department for Quantum Technology, Univeristät Münster, Germany

We present an ultra-fast quantum dot (QD) single-photon source in the telecom C-band, based on InAs/InAlGaAs QD integrated in a circular Bragg grating cavitiy. We observe record-short biexciton decay time of T1=68 ps under resonant two-photon-excitation (TPE), which allows us to generate highly indistinguishable single photons at clock rates > 1 GHz. The two-photon interference visibility of photons emitted via the biexciton-exciton transition was measured in a Hong-Ou-Mandel-type experiment to be 92.4% and 82.6% at clock rates of 100 MHz and 2.5 GHz, respectively. Applying stimulated TPE in the telecom C-Band for the first time, we show that the photon indistinguishability can be further enhanced for exciton photons. Our results show promises to advance QD-based implementations of quantum cryptography to unprecedentedly high clock rates at wavelengths suitable for large-scale fiber-optic networks.

Q 11.5 Mon 18:15 P 7

Enhanced Exciton Dynamics in Free-Standing TMD Heterobilayers — •Marah Alqedra and Ibrahim Sarpkaya — National Nanotechnology Research Center, Bilkent University, Ankara, Turkey

Atomically thin transition-metal dichalcogenide (TMD) van der Waals heterobilayers enable the formation of spatially indirect interlayer excitons (IXs), with electrons and holes residing in different layers, offering long exciton lifetimes and a permanent electric dipole, promising for valley/spin physics and quantum-optical applications. Substrate-supported heterostructures, however, often experience substrate-induced disorder and environmental coupling that degrade IX photoluminescence (PL) emission and reduce optical quality. To overcome these limitations, we prepared suspended heterobilayers free from substrate interaction. Low-temperature PL and time-resolved PL measurements show a strong enhancement of IX emission in suspended heterobilayers compared to conventional supported samples. This indicates suppression of non-radiative losses and environmental dephasing, improving excitonic optical performance, a step toward realizing high-quality 2D-material emitters and quantum-optical devices.

Q 11.6 Mon 18:30 P 7

Wigner functions of pure photonic states emitted by quantum dot sources — •Hubert Lam[1], Petr Steindl[1], Yann Portella[1], Juan R. Álvarez[2], Kiarn Laverick[3], Anton Pishchagin[4], Thi Huong Au[4], Sébastian Boissier[4], Aristide Lemaître[1], Alexia Auffèves[3], Dario A. Fioretto[1,4], and Pascale Senellart-Mardon[1] — [1]Centre de nanosciences et de nanotechnologies, Palaiseau, France — [2]Télécom Paris, Palaiseau, France — [3]MajuLab, Singapore — [4]Quandela, Massy, France

Semiconductor quantum dots are excellent on-demand single-photon sources. Coupled to optical cavities, they emit pure, indistinguishable photons at high rates. While such sources have mainly been used for discrete-variable photonic quantum information processing, their ability to generate complex non-Gaussian states and provide strong single-photon nonlinearity positions them as promising resources for continuous-variable (CV) protocols as well.

We take a first step toward using cavity-coupled quantum dots as CV resources. We measure the Wigner functions of single-photon and photon-number superposition states from our emitter, achieving purities above 90 %. This is enabled by adapting homodyne-like displacement techniques to the high-brightness regime of our source.

These results demonstrate that quantum-dot sources can be harnessed for the generation and engineering of non-Gaussian states and pave the way for continuous-variable quantum information processing with optical solid-state emitters.

Q 11.7 Mon 18:45 P 7

Pulsed to continuous wave microcavity-quantum dot (in)coherent dynamics — •Mio Poortvliet and Wolfgang Löffler — Leiden Institute of Physics, Leiden University, Leiden, The Netherlands

Semiconductor quantum dots are a promising single photon source, when excited correctly. We focus on resonant excitation, this allows coherent control and is flexible to implement. The response from the quantum dot is well understood for continuous wave excitation, where a stream of single photons is produced without well-defined time-bins. Using pulsed excitation light with a pulse length shorter than relevant QD decoherence times is also well understood, population inversion above 50% can produce one photon per time bin deterministically.

In this experiment, we study a charged InGaAs quantum dot in a polarization-split monolithic micro-cavity and excite it using a custom pulse generator enabling pulse lengths from 20 ps to many times the QD lifetime. With this, we investigate how the cavity-quantum dot system behaves under various excitation conditions, from pulsed to continuous-wave, and for different quantum dot and laser detunings. We measure the characteristic chevron pattern of Rabi oscillations, modified by cavity field enhancement and cavity-QD hybridization. We are able to reproduce this data accurately by careful simulation. By simultaneously measuring the second order correlation function we observe how the photon statistics oscillate between anti-bunched and bunched, and by chaning the detuning we measure significant bunching likely from a single photon subtracted coherent state.

Q 12: Quantum Computing and Simulation II

Time: Monday 17:00–18:45 Location: P 10

Invited Talk Q 12.1 Mon 17:00 P 10

Topological pumping and quantum information — •Konrad Viebahn, Yann Kiefer, Zijie Zhu, Lars Fischer, Marius Gächter, Giacomo Bisson, Samuel Jele, Lisa Peters, and Tilman Esslinger — Institute for Quantum Electronics, ETH Zurich, Switzerland

Topological pumps provide a powerful method for transporting particles with remarkable precision by slowly and cyclically modulating a lattice potential. This transport is topologically protected - a feature it shares with the quantum Hall effect - making it inherently robust against noise and experimental imperfections.

In this talk, I will introduce a novel paradigm of this concept: moving beyond the transport of individual particles to the pumping of qubits carrying quantum information. Our experiments, which employ ultracold fermions in dynamical optical lattices [1,2], demonstrate the coherent transport of not only single atoms but also entangled Bell pairs over hundreds of lattice sites. This capability allows us to perform fundamental quantum computations during transport, including high-fidelity two-qubit gates. I will show how we can chain these operations together to build non-local quantum circuits and generate complex entanglement patterns across the lattice.

[1] Zhu et al. PRX (2025), Splitting and connecting singlets in atomic quantum circuits

[2] Kiefer et al. arXiv:2507.22112, Protected quantum gates using qubit doublons in dynamical optical lattices

Q 12.2 Mon 17:30 P 10

Benchmark of transport-induced motional excitations in an 8-qubit quantum processor — •Phil Nuschke[1], Rodrigo Munoz[1], Teresa Meiners[1], Brigitte Kaune[1], and Christian Ospelkaus[1,2] — [1]Institut für Quantenoptik, Leibniz Universität Hannover, Welfengarten 1, 30167 Hannover, Germany — [2]Physikalisch-Technische Bundesanstalt, Bundesallee 100, 38116 Braunschweig, Germany

We present a framework to analyse the effect of transport on the motional states of ions in a trapped-ion quantum processor. By decomposing the shuttling protocol into primitive operations, we can evaluate their heating effects individually and combine results algebraically, avoiding full simulations for entire trajectories. We benchmark this method on an 8-qubit quantum processor, integrating the cost of motional operations at the compiler level.

Q 12.3 Mon 17:45 P 10

A dual-species Rydberg array for distributed quantum information processing — •Adrien Bouscal[1,2,3], Mullai Sampangi[1,2,3,4], Max Gewald[1,2,3], Pit Steinmetz[1,2,3,4], Balázs Dura-Kovács[1,2,3], Mehmet Öncü[1,2,3], Jacopo de Santis[1,2,3], Dimitrios Vasileiadis[1,2,3,4], and Johannes Zeiher[1,2,3] — [1]LMU München, 80799 München, Germany — [2]Max-Planck-Institut für Quantenoptik, 85748 Garching, Germany — [3]Munich Center for Quantum Science and Technology, 80799 München, Germany — [4]Technische Universität München, 85748 Garching, Germany

Quantum error correction requires ancilla qubits that can be replenished, reset, and read out mid-circuit without disturbing the data qubits. A dual-species architecture enables these capabilities through element-selective optical addressing with inherently low crosstalk. We report on the design of a compact dual-element source for a hybrid tweezer array combining rubidium (Rb) and ytterbium (Yb) coupled to an optical cavity. An atomic beam of Yb from an effusion cell is trapped in a 2D MOT after being slowed in a short Zeeman slower, whose magnetic field gradient is produced by the 2D MOT permanent magnets. From this transversely-cooled beam, a 3D MOT and tweezers will be loaded in a separate science cell. We also plan to implement continuous reloading of Rb qubits via transport with an optical conveyor belt from a distant 3D MOT. This platform enables interfacing logical quantum processors with optical modes and opens perspectives for fast feedback, long-lived nuclear-qubit memories, quantum networking, and distributed quantum information processing.

Q 12.4 Mon 18:00 P 10

Mediated Gates and Quantum Cellular Automata in a Dual-Species Rydberg Array — •Alexander Impertro[1,2], Ryan White[1,2,3], Ka Hui Goh[1,2], Vikram Ramesh[3], Shraddha Anand[3], and Hannes Bernien[1,2,3] — [1]Institute for Quantum Optics and Quantum Information, 6020 Innsbruck, Austria — [2]University of Innsbruck, 6020 Innsbruck, Austria — [3]University of Chicago and Pritzker School of Molecular Engineering, Chicago, IL 60637, USA

A key challenge in scaling up quantum processors and simulators is the need to implement individual qubit control in a resource-efficient yet performant manner. Rydberg arrays consisting of two distinct atomic species are a particularly promising platform to achieve this goal, with independent addressing and readout transitions enabling selective qubit control as well as mid-circuit operations. In this talk, we present how such a dual-species architecture allows the execution of a broad class of quantum circuits using only simple global control. Formulated in the framework of quantum cellular automata, we leverage discrete pulse sequences based on high-fidelity interspecies-mediated gates to prepare Bell, GHZ and cluster states, which we can additionally grow into graph-like states with longer-range connectivity. Moreover, the versatile Rydberg interaction landscape provided by two atomic species opens up the possibility to perform long-range multi-qubit gates. Together, these results showcase how dual-species processors enable a highly efficient use of control resources, enhance scalability and thus pave the way for the next generation of quantum information and simulation experiments.

Q 12.5 Mon 18:15 P 10

Measurement Based Quantum Computing with Trapped-Ion Qudits — •Tim Gollerthan[1], Alena Romanova[2], Peter Tirler[1], Manuel John[1], Keshav Pareek[1], Lisa Parigger[1], Raphael Poloczek[1], Timo Spalek[1], Lukas Gerster[1], Michael Meth[1], Wolfgang Dür[2], and Martin Ringbauer[1] — [1]Institut für Experimentalphysik, Universität Innsbruck, Austria — [2]Institut für Theoretische Physik, Universität Innsbruck, Austria

Measurement-based quantum computing (MBQC) is a leading model for quantum computation. In contrast to the circuit model, it exploits highly entangled universal resource state, on which computations are driven by local measurements. This allows for blind quantum computing as a secure technique for cloud-based quantum computing and facilitates stabilizer error correction codes. MBQC has been implemented in a variety of platforms, including photonic and trapped-ion quantum hardware in recent years. However, the vast majority of work is restricted to qubit-based cluster states. Employing multi-level information carriers instead has the potential to elevate MBQC to a new level of potential, since qudit systems feature a more extensive gate set, enhanced efficiency in encoding and computation as well as more complex entanglement structures. In consequence, resource states that extend beyond the well-known qubit cluster state, can be harnessed for MBQC. The presentation will report on the exploration of Qudit-MBQC with a state-of-the-art trapped-ion quantum processor.

Q 12.6 Mon 18:30 P 10

Integrated generation of photonic graph states for measurement-based quantum computing — •Jeldrik Huster[1,2], Louis Hohmann[1,2], and Stefanie Barz[1,2] — [1]Institute for Functional Matter and Quantum Technologies, University of Stuttgart, 70569 Stuttgart, Germany — [2]Center for Integrated Quantum Science and Technology (IQST)

Photonic quantum devices have been used to demonstrate a broad range of quantum applications, namely quantum computation, communication and network applications. Essential for the scaling to higher qubit numbers, are integrated solutions in the telecom band, due to their small footprint, high phase stability and low loss connectivity. Most photonic implementations rely on multipartite entangled states, especially graph states. Here, we present our recent progress on a silicon on insulator photonic chip for the generation of graph states with up to four qubits. We generate four-qubit Greenberger-Horne-Zeilinger (GHZ) and linear graph states with fidelities of over 83% and 75%, respectively. These states are used to show photonic measurement-based quantum computing (MBQC). We demonstrate single-qubit and two-qubit gates as well as the implementation of Grover's search and Deutsch's algorithm. This is made possible by the chip's high coupling efficiency to single modes fibres and reconfigurability via tuneable beam splitter and phase shifters.

Q 13: Nuclear Clocks

Time: Monday 17:00–19:00 Location: P 11

Q 13.1 Mon 17:00 P 11

Setup for Laser Excitation of the ^{229}Th Nucleus in a Cryogenic Environment — •Florian Zacherl[1], Lennart Guth[2], Jan-Hendrik Oelmann[2], Anant Agarwal[2], Tobias Heldt[2], Keerthan Subramanian[1], Srinivasa Pradeep Arasada[1], Valerii Andriushkov[3,4], Ke Zhang[1], Yumiao Wang[1,5], Darius Fenner[1], José R. Crespo López-Urrutia[2], Christoph E. Düllmann[1,3,4], Dmitry Budker[1,3,4,6], Thorsten Schumm[7], Ferdinand Schmidt-Kaler[1], and Lars von der Wense[1] — [1]Johannes Gutenberg University Mainz, Germany — [2]Max-Planck-Institut für Kernphysik, Heidelberg, Germany — [3]Helmholtz Institute Mainz, Germany — [4]GSI Helmholtzzentrum für Schwerionenforschung, Darmstadt, Germany — [5]Fudan University, Shanghai, China — [6]University of California, Berkeley, USA — [7]Vienna University of Technology, Austria

The low isomeric energy level of only 8.4 eV in ^{229}Th places the transition wavelength in the vacuum-ultraviolet (VUV) and therefore provides the unique opportunity to excite it with optical lasers. The described setup aims to excite the nuclei of Th^{4+} ions in a $Th:CaF_2$ crystal at around 148 nm with a VUV frequency comb. The crystal is placed and excited in a He cryogenic environment to probe for temperature dependent transition frequency shifts as well as variations in decay time at very low temperatures down to 4 K.

This work is supported by the BMFTR Quantum Futur II Grant Project *NuQuant* (FKZ 13N16295A) and DFG Project *TACTICa* (grant agreement no.495729045).

Q 13.2 Mon 17:15 P 11

Commissioning of a Low-Energy Ion Beamline for Future ^{229}Th Nuclear Clock Applications Using a Cs Ion Source as a Proxy — •Srinivasa Pradeep Arasada[1], Florian Zacherl[1], Valerii Andriushkov[2,3], Keerthan Subramanian[1], Jonas Stricker[1,2], Ke Zhang[1], Yumiao Wang[1,4], Darius Fenner[1], Ferdinand Schmidt-Kaler[1], Dmitry Budker[1,2,3,5], Christoph E. Düllmann[1,2,3], and Lars von der Wense[1] — [1]Johannes Gutenberg Universität Mainz, Germany — [2]Helmholtz Institute Mainz, Germany — [3]GSI Helmholtzzentrum für Schwerionenforschung GmbH, Darmstadt, Germany — [4]Fudan University, Shanghai, China — [5]University of California, Berkeley, USA

The development of a ^{229}Th nuclear clock requires robust methods for extracting and preparing low-energy thorium ion beams. As a critical step toward this goal, we report the successful commissioning of a new ion beamline, comprising a buffer-gas stopping cell for thermalization and an RFQ ion guide for beam cooling. Using a stable cesium beam as a proxy for future ^{229}Th experiments, we have established and optimized the complete ion transport sequence. A MCP detector provided clear evidence that the ions were successfully extracted, guided, and detected. This work validates the core functionality of the apparatus and establishes the necessary baseline for subsequent efficiency measurements and the future integration of a ^{233}U source at the University of Mainz. This project is supported by the BMFTR Quantum Futur II Grant Project *NuQuant*(FKZ 13N16295A) and DFG Project *TACTICa*(grant agreement no.495729045).

Q 13.3 Mon 17:30 P 11

Towards lifetime measurement of the nuclear clock isomer $^{229m}Th^{3+}$ via hyperfine laser spectroscopy in a cryogenic Paul trap — •Georg Holthoff, Kevin Scharl, Tamila Teschler, Daniel Moritz, Markus Wiesinger, and Peter G. Thirolf — Ludwig-Maximilians-Universität München

The Thorium-229 isomer with its uniquely low lying 8.4 eV nuclear excited state is the so far most promising candidate for a nuclear frequency standard ('nuclear clock'). Due to the long lifetime of the excited state (ca. 2000 s in vacuum, expected to be measured precisely in our experiment), thus low emission rate, and ca. 148.4 nm VUV wavelength of the emitted photon, direct fluorescence detection is extremely difficult in the trapped ion approach. At LMU Munich, determining if nuclear excitation of $^{229m}Th^{3+}$ in our cryogenic Paul trap has occurred will therefore be performed via a double-resonance method as proposed in 2003 by Peik et al. For this we discuss predictions of the hyperfine structure of the ground and isomeric state as well as the isomer shift. Ongoing experimental work on hyperfine spectroscopy of sympathetically laser-cooled $^{229m}Th^{3+}$ will also be presented. The choice of hyperfine transitions to differentiate the two states and the influence of their addressing scheme is discussed for both 690 nm and 984 nm lasers. Furthermore, experimental results for different hyperfine addressing schemes using EOMs driven by voltage controlled oscillators (VCOs) are discussed. Supported by the European Research Council (ERC): Grant 856415.

Q 13.4 Mon 17:45 P 11

A cryogenic Paul trap for spectroscopy of the nuclear clock isomer $^{229m}Th^{3+}$ — •Markus Wiesinger, Georg Holthoff, Kevin Scharl, Tamila Teschler, Daniel Moritz, and Peter G. Thirolf — Ludwig-Maximilians-Universität München

The ^{229}Th nucleus has the unique property of an extremely low lying isomeric first excited state (denoted ^{229m}Th). With an excitation energy of 8.356 eV – corresponding to a wavelength of 148.4 nm – and an expected lifetime of the ionic thorium isomer in vacuum of about 2000 s, the isomeric state can be directly excited with laser light from state-of-the-art VUV laser systems. Consequently, ^{229}Th is the ideal candidate for a nuclear optical clock. Furthermore, the nuclear clock transition has an about 10^3 times larger sensitivity to time variation of the fine structure constant compared to transitions in other atoms.

While the isomeric state was recently directly excited with laser light in ^{229}Th doped CaF_2 and other solid-state crystals, the nuclear clock project at LMU focusses on the trapped ion approach with laser-cooled $^{229}Th^{3+}$, which features suitable electronic transitions for fast nuclear state readout and extremely low systematic uncertainties.

This talk will give an overview of the cryogenic Paul trap apparatus routinely applied for sympathetic laser-cooling of $^{229(m)}Th^{3+}$ ions embedded in mixed-species $^{229(m)}Th^{3+}/^{88}Sr^{+}$ Coulomb crystals. We will show simultaneous fluorescence imaging of trapped $^{88}Sr^{+}$ ions at 422 nm and $^{229}Th^{3+}$ ions at 690 nm using two cameras, laying the foundations for measuring the lifetime of $^{229m}Th^{3+}$ in vacuum and for quantum state readout after VUV excitation of the nuclear transition.

Q 13.5 Mon 18:00 P 11

Towards Continuous-Wave Laser Excitation of the Th-229 Nuclear Isomer Sympathetically Cooled with Ca Ions — •Ke Zhang[1], Valerii Andriushkov[2,3], Yumiao Wang[1], Darius Fenner[1], Keerthan Subramanian[1], Florian Zacherl[1], Srinivasa Pradeep Arasada[1], Jonas Stricker[1,2], Christoph E. Düllmann[1,2,3], Dmitry Budker[1,2,3,4], Ferdinand Schmidt-Kaler[1], and Lars von der Wense[1] — [1]Johannes Gutenberg University Mainz, Germany — [2]Helmholtz Institut Mainz, Germnay — [3]GSI Helmholtzzentrum für Schwerionenforschung — [4]Department of Physics, University of California, Berkeley, USA

We investigate an experimental scheme for the continuous-wave laser excitation of the nuclear isomeric state in $^{229}Th^{3+}$. Thorium recoil ions are extracted from a radioactive source, mass-selected to obtain purified $^{229}Th^{3+}$, and injected into a linear Paul trap via an RF quadrupole guide. Inside the trap, the $^{229}Th^{3+}$ ions are sympathetically cooled through Coulomb interaction with sub-Doppler-cooled $^{40}Ca^{+}$ ions, reaching the motional ground state in the Lamb–Dicke regime. A continuous-wave laser stabilized to the expected nuclear transition energy will coherently drive the isomeric transition. This approach aims to demonstrate the feasibility of precision nuclear spectroscopy in a sympathetically cooled trapped-ion system, enabling the way for ion-based nuclear optical clocks and advancing fundamental research in nuclear and atomic physics. The work is supported by the DFG Project *TACTICa* (grant agreement no. 495729045) and the BMFTR Quantum Futur II Project *NuQuant* (FKZ 13N16295A).

Q 13.6 Mon 18:15 P 11

A solid-state VUV laser at 148.4 nm for the ^{229m}Th nuclear clock — •Keerthan Subramanian[1], Nutan Kumari Sah[1], Florian Zacherl[1], Srinivasa Pradeep Arasada[1], Valerii Andriushkov[2,3], Yumiao Wang[1], Ke Zhang[1], Darius Fenner[1], Gaurav Jha[1], Jonas Stricker[1,2,3], Christoph E. Düllmann[1,2,3], Dmitry Budker[1,2,3,4], Ferdinand Schmidt-Kaler[1], and Lars von der Wense[1] — [1]Johannes Gutenberg Universität Mainz — [2]Helmholtz Institut Mainz — [3]GSI Helmholtzzentrum für Schwerionenforschung — [4]University of California, Berkeley

The recent laser excitation of ^{229m}Th has ushered in a new era with the prospect of building a nuclear clock with unprecedented stability and susceptibility to the variation of fundamental constants. A continuous-wave (cw) clock laser at 148.4 nm is indispensable for the realization of such a clockwork based ^{229m}Th.

$BaMgF_4$ (BMF) is a suitable candidate for second harmonic generation (SHG) due to its second order non-linearity, high VUV transparency and ferroelectric properties making it amenable to periodic poling (pp). In order to reach reasonable powers, ppBMF is placed inside an enhancement resonator and intracavity SHG is performed. The projected powers make it a viable scheme for the realization of a compact all solidstate cw laser necessary for the realization of a solid-state as well as a single-ion nuclear clock. Recent progress towards this goal will be presented. This work is supported by BMFTR Quantum Futur II Grant NuQuant under grant agreement no FKZ 13N16295A.

Q 13.7 Mon 18:30 P 11

Design and optimization of a VUV beamline for nuclear laser excitation of a single ^{229}Th^{3+} ion — •Tamila Teschler[1], Georg Holthoff[1], Daniel Moritz[1], Kevin Scharl[1], Markus Wiesinger[1], Johannes Weitenberg[2], Stephan H. Wissenberg[2], and Peter G. Thirolf[1] — [1]Ludwig-Maximilians-Universität München (LMU) — [2]Fraunhofer Institute for Laser Technology (ILT), Aachen

Direct frequency-comb spectroscopy represents an advanced technique for achieving narrowband nuclear laser excitation. Within an ERC Synergy project, a VUV frequency comb developed at Fraunhofer ILT will be combined with a cryogenic Paul trap system at LMU Munich to enable the excitation of the isomeric state in ^{229}Th using laser radiation at $\lambda \approx 148\,$nm. This is a major milestone toward the implementation of a nuclear clock based on the unique nuclear properties of the nuclear isomer ^{229}Th, enabling highly precise timekeeping and providing insights into new physics beyond the Standard Model. The approach relies on frequency-comb interrogation of a single, sympathetically laser-cooled ^{229m}Th^{3+} ion. To ensure sufficient excitation probability, a VUV focus diameter of about $3\,\mu$m is required, imposing strict limitations on the optical beamline design to minimize aberrations and transmission loss. The procedures for the design and optimization of a VUV beamline from the VUV laser source to the trapped-ion environment will be presented. Funding: Thorium Nuclear Clock ERC Synergy project, Grant Agreement No. 856415.

Q 13.8 Mon 18:45 P 11

Towards nuclear laser excitation of ^{229}Th ions — •Vishal Lal, S. Sagar Maurya, Gregor Zitzer, Niels Irwin, Johannes Tiedau, Maksim V. Okhapkin, and Ekkehard Peik — Physikalisch-Technische Bundesanstalt, Braunschweig

The recently demonstrated laser excitation of low-energy nuclear transition in ^{229}Th using table-top laser systems, has opened prospects for a new generation of optical clocks based on a nuclear transition. Since the nucleus itself is much smaller, much less polarizable and very well shielded by the electrons around, the effect of external electric fields and field gradients are expected to be significantly smaller compared to electronic transition used in most of the state-of-the-art optical atomic clocks (trapped ions and optical lattice clocks). The laser excitation of the nucleus can be detected efficiently in a double-resonance method by probing the hyperfine structure of a transition in the electron shell.

We here report our experimental setup and advances in laser excitation of the ^{229}Th nucleus and relevant hyperfine structure suitable for nuclear spectroscopy in buffer gas cooled of ^{229}Th^{1+}, ^{229}Th^{2+}, and sympathetically laser cooled ^{229}Th^{3+} ions.

Q 14: Precision Spectroscopy of Atoms and Ions I (joint session A/Q)

Time: Monday 17:00–19:00 Location: N 3

Invited Talk Q 14.1 Mon 17:00 N 3

Isotope shifts and population dynamics in neutron-rich Mg$^+$ measured with MIRACLS — •Konstantin Mohr for the MIRACLS-Collaboration — GSI Helmholtzzentrum für Schwerionenforschung

The **M**ulti **I**on **R**eflection **A**pparatus for **C**ollinear **L**aser **S**pectroscopy (MIRACLS) combines a multi-reflection time-of-flight (MR-ToF) device and collinear laser spectroscopy (CLS) to overcome the current sensitivity limits of fluorescence-based collinear laser spetroscopy. By multiple ion-photon interactions in the MR-ToF device, the MIRACLS setup at the ISOLDE facility at CERN enables CLS studies of short-lived radioactive isotopes far from stability with very low yields, such as ^{34}Mg.

Simultaneous collinear and anticollinear spectroscopy of the D_1 and D_2 transitions in $^{24-34}$Mg$^+$ ions has been performed, with particular interest on ^{33,34}Mg at the island of inversion. To extract isotope shifts – and thus probe shape coexistence driven by intruder states around the N=20 shell – a detailed understanding of the population dynamics within the hyperfine structure of the odd isotopes is essential. The resulting complex line shapes were disentangled and the effects of population redistribution quantified through rate-equation based simulations.

In this contribution, we discuss the distinctive features of the MIRACLS approach and experimental challenges associated with multiple photon-ion interactions. Furthermore, first results of the isotope shifts of the Mg isotopic chain will be presented.

Q 14.2 Mon 17:30 N 3

Precision calculation of the bound-electron g factor in molecular hydrogen ions — •Ossama Kullie[1], Hugo Nogueira[2], and Jean-Philippe Karr[2,3] — [1]Theoretical Physics at Institute for Physics, University of Kassel, Germany — [2]Laboratoire Kastler Brossel, Sorbonne Université, CNRS, ENS-Université PSL, Collège de France, 4 place Jussieu, F-75005 Paris, France — [3]Université Evry Paris-Saclay, Boulevard François Mitterrand, F-91000 Evry, France

In this work [1], we present calculations of the bound-electron g-factor for a wide range of rovibrational states in the ground electronic state ($1s\sigma$) of the molecular hydrogen ions H_2^+ and HD^+. Relativistic and QED corrections of orders up to α^5 are taken into account. All contributions are calculated in a nonrelativistic QED framework, except for relativistic corrections of order $(Z\alpha)^4$ and above, which are obtained by calculating the relativistic g-factor using a precise solution of the two-center Dirac equation with FEM [2]. A relative accuracy of $\sim 10^{-11}$ is achieved for the scalar g-factor component, with an improvement by more than three orders of magnitude over previous calculations. These results are useful for internal state identification and rovibraional spectroscopy of single molecular hydrogen ions in Penning traps, and open a new avenue towards precision tests of QED. Finally, a comparison with experimental result of high-precision Penning-trap spectroscopy of the ground-state spin structure of HD^+ [2] is given. [1] Ossama Kullie, Hugo D. Nogueira and Jean-Philippe Karr, Phys. Rev. A **112**, 052813 (2025). O. Kullie et. al., Phys. Rev. A 105, 052801 (2022). [3] Charlotte M. König et. al., Phys. Rev. Lett. (2025) under review.

Q 14.3 Mon 17:45 N 3

Hyper-EBIT: The development of a source for very highly charged ions — •Luca Yannik Geissler, Matthew Bohman, Fabian Heisse, Philipp Justus, Anton Gramberg, Jonathan Morgner, Charlotte Maria König, Jialin Liu, José Ramon Crespo López-Urrutia, Sven Sturm, and Klaus Blaum — Max-Planck-Institut für Kernphysik, 69117 Heidelberg

Quantum electrodynamics (QED) is considered to be the most successful quantum field theory in the Standard Model. Its most precise test follows from the comparison of the measured g-factor of the free electron and its prediction by QED. While this comparison tests QED at small electromagnetic field strengths, highly charged ions (HCI) allow performing a similar test at much stronger fields. In HCI, only the innermost electron(s) remain, which experience strong electric fields of up to $10^{16}\ \frac{\mathrm{V}}{\mathrm{cm}}$ due to the vicinity of the electrons and the nucleus. An experiment that enables such precision studies is ALPHATRAP[Sturm et al., EPJST 227, 1425 (2019)], a cryogenic Penning-trap setup dedicated to measuring the bound-electron magnetic moments of HCIs with high precision. The most stringent test of the bound-electron g-factor performed by ALPHATRAP to date was conducted with hydrogen-like tin[Morgner et al., Nature 622, 53 (2023)]. To extend these high-field tests to heavier HCIs, such as $g_j(^{208}\mathrm{Pb}^{81+})$, an electron-beam ion trap (EBIT), the Hyper-EBIT, was built at MPIK to produce such ions. It is designed to provide electron-beam energies of up to 300 keV and beam currents of up to 500 mA. This contribution presents the latest developments and current status of the Hyper-EBIT.

Q 14.4 Mon 18:00 N 3

Magneto-optical trapping of Zinc — •Lukas Möller, Felix Waldherr, and Simon Stellmer — Universität Bonn, Germany

Laser-cooling and trapping of neutral atoms is a widely used technique in contemporary atomic physics. The element zinc, an alkaline-earth-like metal, is a promising candidate for a new optical clock. Work on zinc also motivates the development of new cw-laser sources in the UV range, since its strong cooling transition lies at 213.9 nm. We report magneto-optical trapping of all 5 stable isotopes of Zinc, as the first step towards spectroscopy of the clock transition.

Q 14.5 Mon 18:15 N 3

Isotope shifts of the $^1S_0 \rightarrow {}^3P_1$ intercombination line in zinc — •Felix Waldherr, Lukas Möller, and Simon Stellmer — Universität Bonn, Germany

Zinc is a promising element for optical precision measurements due to its low black-body radiation sensitivity. We study the intercombination line at 308 nm using Doppler-free spectroscopy in a thermal zinc vapor. A narrow-linewidth, frequency-stabilized laser system enables the determination of resonance frequencies for all stable isotopes. The resulting isotope shifts offer a basis for future work in nuclear structure. In addition, the 308 nm transition is of direct relevance for laser-cooling schemes, where it can serve as a narrow second-stage cooling transition following the strong 214 nm cooling line.

Q 14.6 Mon 18:30 N 3

Towards the first 1S-2S Measurement in Atomic Tritium — •Hendrik Schürg and Randolf Pohl — Johannes Gutenberg-Universität Mainz, Institut für Physik, QUANTUM & Exzellenzcluster PRISMA$^+$, Mainz, Germany

Laser spectroscopy is an effective method for obtaining high-precision results for the root-mean-square charge radii of nuclei. Here, we outline a route towards the first measurement of the 1S-2S interval in atomic tritium – giving access to the triton charge radius through the hydrogen-tritium 1S-2S isotope shift. Our approach relies on a compact radio-frequency discharge cell that will safely confine the radioactive tritium gas and enables optogalvanic detection of the resonant excitation to the 2S state via the laser-induced perturbation of the plasma's impedance. So far, we have demonstrated Doppler-free intermodulated optogalvanic spectroscopy of the hydrogen Balmer-β fine structure components near 486 nm. For the two-photon 1S-2S transition at 243 nm, we analyze expected line shifts and broadenings, and estimate an optogalvanic signal strength based on a collisional-radiative plasma model. Achieving the required laser intensity will involve the integration of the discharge cell into a deep-uv enhancement cavity.

Q 14.7 Mon 18:45 N 3

Continuation of Laser-Based HV Measurements at COALA — •Hendrik Bodnar, Kristian König, and Wilfried Nörtershäuser — Institute for nuclear physics, TU Darmstadt

The ALIVE experiment at the Collinear Apparatus for Laser spectroscopy and Applied sciences (COALA) at TU Darmstadt aims to measure high voltages in the tens-of-kilovolts range with ppm precision. Conventional techniques rely on voltage dividers that reduce the high-voltage to about 10 V. A drawback of these dividers, however, is the time-dependent drift of their division ratio. In contrast, the ALIVE experiment determines the high-voltage via the Doppler-shift of a transition line in an ion, which has been accelerated using the high-voltage under investigation. Therefore, the ion beam is superimposed with a laser beam and the laser frequency is adjusted to excite the ions. When the rest-frame transition frequency and the laboratory laser frequency are known and measured with sufficient accuracy, respectively, the voltage experienced by the ions can be calculated.

The best precision achieved so far with this approach was 5 ppm [1]. This limitation originated mainly from the design of the acceleration region and its influence on the ion beam. The new design of the acccel-eration region and first measurements will be presented. Funding from the DFG under project number 461079926 and support under project ID 279384907-SFB 1245 is acknowledged.

[1] Krämer et al., Metrologia 55 268, (2018)

Q 15: Precision Mass Spectrometry (joint session MS/Q)

Time: Monday 17:00–19:00 Location: N 6

Invited Talk Q 15.1 Mon 17:00 N 6

Pushing the Boundaries at FRIB: High-Precision Mass Measurements Near The Driplines — •Franziska Maria Maier, Scott Campbell, Hannah Erington, Christian Ireland, and Ryan Ringle — FRIB, USA

With new radioactive-ion-beam facilities such as FRIB becoming operational, the properties of nuclei in close proximity to the driplines are coming within reach of high-precision measurements. Within the last two years, at a fraction of FRIB's ultimate beam intensity, we used the LEBIT facility to successfully perform Penning-trap mass measurements of ^{22}Al [1], ^{101,103}Sn [2,3] and ^{23}Si [4]. These masses provide insights into the smoothness of the mass surface, help assess isospin symmetry breaking and offer valuable anchor points for nuclear models - especially for predicting properties near the driplines, where experimental data remain scarce. As FRIB ramps up its beam intensity, the production of many more nuclei will enable new and exceptional research opportunities. However, the short half-lives of many of these nuclei pose challenges for Penning-trap mass spectrometry. To overcome these, we are developing MR-ToF devices at FRIB, that will also expand FRIB's mass separation capabilities [5,6].

[1] S. Campbell et al., PRL 132, 152501 (2024)
[2] C.M. Ireland, F.M. Maier et al., PRC 111, 014314 (2025)
[3] C.M. Ireland et al., arxiv.org/abs/2510.11815
[4] F.M. Maier et al., PRC 112, 014329 (2025)
[5] F.M. Maier, C.M. Ireland et al., arxiv.org/abs/2509.16428
[6] C.M. Ireland, F.M. Maier et al., arxiv.org/abs/2510.11741

Q 15.2 Mon 17:30 N 6

A Laser-Ablation Ion Source for the ISOLTRAP Experiment — •Paul Florian Giesel for the ISOLTRAP-Collaboration — Universität Greifswald, Institut für Physik, Greifswald, Germany

ISOLTRAP is a precision mass spectrometer at ISOLDE/CERN dedicated to measure the masses of short-lived radionuclides far from stability. It utilizes both multi-reflection time-of-flight (MR-ToF) [1] and Penning-trap mass spectrometry [2-4]. Conversion of the resulting mass values into nuclear binding energies provides insights into the underlying nuclear forces and structures.

All measurements at ISOLTRAP rely on suitable reference ions. This contribution will present the laser-ablation ion source (LAIS), developed to supply a versatile set of reference species produced from various target materials, including e.g. carbon-cluster ions or aluminum and bismuth ions. This enables flexible calibration across a broad mass range. Beyond delivering reference ions, this source facilitates characterization studies of the ISOLTRAP setup, which can be performed in combination with an alkali ion source. An example is the investigation of space-charge effects in the MR-ToF analyzer with $^{13}\mathrm{C}^{12}\mathrm{C}_{10}^{+}$ and $^{133}\mathrm{Cs}^{+}$ ions as well as the formation of hydrides and oxides in the ISOLTRAP RFQ cooler-buncher.

[1] Wolf R. N. et al., Int. J. Mass Spectrom. 349-350:123-133 (2013)
[2] M. König, et al., Int. J. Mass Spectrom. 142, 95 (1995)

[3] S. George, et al., Int. J. Mass Spectrom. 264, 110 (2007)
[4] S. Eliseev, et al., Phys. Rev. Lett. 110, 082501 (2013)

Q 15.3 Mon 17:45 N 6

High-precision Q-value measurements for neutrino physics using the JYFLTRAP Penning trap — •Jouni Ruotsalainen[1], Elina Kauppinen[1], Maxime Mougeot[1], Tommi Eronen[1], Anu Kankainen[1], Jouni Suhonen[1,2], Vikas Kumar[1], Marek Stryjczyk[1], Marlom Ramalho[1], Zhuang Ge[1], and Jenni Kotila[2,3] — [1]University of Jyvaskyla, Department of Physics, Accelerator Laboratory, P.O. Box 35(YFL) FI-40014 University of Jyvaskyla, Jyväskylä, Finland — [2]International Centre for Advanced Training and Research in Physics (CIFRA), P.O. Box MG12, 077125 Bucharest-Măgurele, Romania — [3]Finnish Institute for Educational Research, University of Jyväskylä, P.O. Box 35, Jyväskylä FI-40014, Finland

In this contribution, I will present the results and conclusions of the precise Q-value measurements of the $^{110}Ag^{m}$ beta decay, and ^{104}Ru and ^{122}Sn double-beta decays, and the utilized JYFLTRAP double Penning trap system at the University of Jyväskylä, Finland. These nuclides are possible candidates for future experiments studying the mass of the neutrino and whether the neutrino is its own antiparticle. In collaboration with the nuclear theory group at the University of Jyväskylä, the half-lives of the decays were calculated to determine the feasibility of observing these decays. While the $^{110}Ag^{m}$ was determined to be a suitable candidate for neutrino mass measurements, the half-lives of ^{104}Ru and ^{122}Sn neutrinoless double-beta decay were estimated to be too long for the decays to be observed with current experimental sensitivity.

Q 15.4 Mon 18:00 N 6

High-Precision Mass Measurements of Actinides at TRIGA-Trap for Nuclear Structure Studies — •Tanvir Sayed[1], Klaus Blaum[1], Michael Block[2,3,4], Burcu Cakirli[1], Stanislav Chenmarev[1], Christoph Düllmann[2,3,4], Szilard Nagy[1], and Dennis Renisch[2,3] — [1]Max-Planck-Institut für Kernphysik, Heidelberg, DE — [2]Helmholtz-Institut Mainz, DE — [3]Department Chemie - Standort TRIGA, Mainz, DE — [4]GSI Helmholtzzentrum für Schwerionenforschung, Darmstadt, DE

Actinides encompass an important region of the chart of nuclides with great relevance in nuclear and astrophysics research. The TRIGA-Trap experiment – set-up in the TRIGA research reactor hall at the University of Mainz – involves high-precision mass measurements of heavy radioactive nuclides, in particular actinides, with a double Penning-Trap mass spectrometer [1,2]. Recent measurements include nuclides in the Pu isotopic chain namely ^{238}Pu, ^{239}Pu, ^{240}Pu, ^{242}Pu. The precise masses can be used to compute mass filters, such as S_{2n} (two-neutron separation energies), to explore nuclear structure in heavy, deformed nuclei as well as test predictions from present nuclear shell models. This presentation will provide an overview of the current status of the experiment, discuss recent results along with their application in nuclear structure evaluation, and outline future prospects.

References: [1] J. Ketelaer et al. Nucl. Instrum. Meth. A 594, 162-177 (2008). [2] S. Chenmarev, S. Nagy, J.J.W. van de Laar et al. Eur. Phys. J. A 59(2), 29 (2023).

Q 15.5 Mon 18:15 N 6

Mass measurements of neutron-deficient nuclides close to the N = Z line with the FRS Ion Catcher — •Nived Keeppalli[1] and Gabirella K.Koncz[1,2] for the Super-FRS Experiment-Collaboration — [1]II. Physikalisches Institut, Justus-Liebig-Universität Gießen, Germany — [2]School of Physics and Astronomy, University of Edinburgh, United Kingdom

Mass measurements near the N = Z line were performed with the multiple-reflection time-of-flight mass spectrometer (MR-TOF-MS) at the FRS Ion Catcher at GSI Darmstadt. The MR-TOF-MS enables high precision mass measurements of exotic species having few ms half-life and low production cross sections (∼nb), with high mass resolving power (10^6) and accuracy ($\delta m/m \approx 10^{-8}$).

In this contribution, results from the measurement campaigns carried out near the N = Z line will be presented, including the first direct mass measurement of ^{93}Pd, the one-proton-decay daughter of the (21+) isomer in ^{94}Ag, reducing the mass uncertainty by an order of magnitude. The results indicate that the excitation energies of the parent states responsible for the one-proton (1p) and two-proton (2p) decays in ^{94}Ag differ by 10 standard deviations, pointing towards an incompatibility in the previously reported decay scheme of the 1p and 2p branches. Moreover, the possibility of the existence of two structurally different, high-spin states in ^{94}Ag, feeding the 1p and 2p decay branches was studied, performing state-of-the-art shell-model and mean-field calculations.

Q 15.6 Mon 18:30 N 6

Recent mass measurements and the first application of mass-selective re-trapping at ISOLTRAP — •Daniel Lange for the ISOLTRAP-Collaboration — Max-Planck-Institut für Kernphysik, Heidelberg, Germany

The Isoltrap mass spectrometer [1], located at ISOLDE/CERN, performs high-precision mass measurements of short-lived, exotic nuclides far from stability. These measurements provide direct access to nuclear binding energies, which reflect the underlying nuclear interactions and enable studies in nuclear structure and nuclear astrophysics, among others. Precision mass measurements at the Isoltrap mass spectrometer are performed using various ion traps, including a tandem Penning-trap system and a multi-reflection time-of-flight mass spectrometer (MR-ToF MS). The latter is particularly well-suited for both efficient mass separation and fast, precise mass measurements.
In this contribution, recent mass measurements of neutron-deficient cadmium isotopes in the direct vicinity of the doubly-magic self-conjugate ^{100}Sn nucleus will be presented. Furthermore, the advancements in ion purification with the first application of the mass-selective re-trapping technique [2], enabled by a newly implemented mini-RFQ following the MR-ToF MS, will be shown. Based on the mass measurement of neutron-rich argon using this technique, the feasibility of low-yield experiments in the presence of extremely abundant isobaric contamination and its limitations will be demonstrated.

[1] Lunney, D. *et al.*, J. Phys. G: Nucl. Part. Phys. 44, 064008 (2017)
[2] Dickel, T. *et al.*, J. Am. Soc. Mass Spectrom. 28, 1079-1090 (2017)

Q 15.7 Mon 18:45 N 6

Schottky + Isochronous Mass Spectrometry: Methodology and Results (on behalf of the Experimental Storage Ring Collaboration) — •David Freire Fernandez — University of Cologne, Cologne, Germany

We present a detailed account of Schottky+Isochronous Mass Spectrometry (S+IMS), a novel experimental technique for high-precision nuclear measurements in heavy-ion storage rings. This hybrid method combines the isochronous mode of the GSI-ESR with non-destructive, time-resolved resonant Schottky detectors. We describe the experimental setup, ring tuning procedures, and data analysis workflow. The technique achieves a mass resolving power enabling the separation of isomers with excitation energies down to 100 keV.

To demonstrate the method's capabilities, we present high-precision mass measurements from recent experimental campaigns. These results determine nuclide masses with uncertainties in the keV range, confirming most literature values while revealing significant deviations and improved precision for specific cases, such as 72As and 69As. This work details the methodological foundation for the recent observation of the two-photon decay of 72Ge (Phys. Rev. Lett. 133, 022502) and establishes S+IMS as a powerful tool for exploring short-lived isomers across the nuclear landscape.

Q 16: Ultracold Matter III – Fermions (joint session Q/A)

Time: Tuesday 11:00–13:00 Location: P 2

Q 16.1 Tue 11:00 P 2

Quantum gas microscopy of three-flavor Hubbard systems — •Jan Deppe[1], Jirayu Mongkolkiattichai[2], Liyu Liu[2], Sohail Dasgupta[3], Kaden R. A. Hazzard[3], and Peter Schauss[1,2] — [1]Institute for Quantum Physics, University of Hamburg — [2]University of Virginia — [3]Rice University

This talk will highlight our recent published results at our quantum gas microscope. We demonstrate site- and flavor-resolved imaging of three-component Fermi gases in the Hubbard regime. Extending beyond the SU2 case, three-flavor systems allow access to a wide range of novel exotic quantum phases relevant for models of quantum chromodynamics in lattices. Using the three lowest hyperfine states of Li 6, we realize a balanced mixture in a 2D square lattice with individually tunable interactions for all three flavor pairs.

Our measurements reveal the formation of three-flavor Mott insulators, flavor-selective localization, and selective pairing, observed at temperatures approaching the tunneling scale. Flavor-resolved detection enables reconstruction of pairing correlations, including both onsite and nearest-neighbor contributions, and allows us to directly detect triply occupied sites (triplons), which remain stable despite strong interactions. By exploiting full interaction control via Feshbach resonances, we map out the phase diagram of the three-flavor Fermi system, identifying regimes of flavor-selective pairing, competing attractive pairing, and the Mott-insulating regime.

Finally, it will shortly present the relocation of the experiment from Charlottesville, USA, to Hamburg, Germany and its current state.

Q 16.2 Tue 11:15 P 2

Spectroscopy of excitons and spin-waves in an optical superlattice — •Johannes Obermeyer[1,2], Petar Bojović[1,2], Si Wang[1,2], Marnix Barendregt[1,2], Dorothee Tell[1,2], Immanuel Bloch[1,2,3], and Titus Franz[1,2] — [1]Max-Planck-Institut für Quantenoptik, Garching, Germany — [2]Munich Center for Quantum Science and Technology, Munich, Germany — [3]Ludwig-Maximilians-Universität, München, Germany

In our quantum gas microscope, we load a balanced spin mixture of fermionic Li-6 atoms into a single plane of a 3D optical superlattice. Our precise individual control of the long and short lattice amplitudes allows to create bound doublon-holon (Mott exciton) and spinon excitations via lattice amplitude modulation. Depending on the structure of the superlattice, excitations of s-, p- and d-orbital kind are possible. Further, through controlled quenches of a Mott insulator state with Heisenberg spin interactions, we can access dynamical correlation maps of bimagnon-like bound states using time-resolved measurements.

Q 16.3 Tue 11:30 P 2

Quantum engine and thermometry in the BEC-BCS crossover — •Felix Lang, Alexander Guthmann, Louisa Kinesberger, Eleonora Lippi, and Artur Widera — RPTU University Kaiserslautern-Landau, 67663 Kaiserslautern, Germany

Heat engines have become an integral part of our lives, as they allow us to turn heat into physical work. Quantum heat engines can run at higher efficiencies than their classical counterparts [1]. Our platform uses ultracold quantum gases of ^{6}Li in a harmonic trap along the crossover from a Bardeen-Cooper-Schrieffer (BCS) superfluid to a Bose-Einstein condensate (BEC) allowing us to utilize quantum statistics of fermions and bosons to perform work in a thermodynamic engine cycle.

In this talk, we present experimental results on the engine's efficiency over a large parameter space spanned by temperature and interaction strength. A key component of our analysis is thermometry based on the virial expansion of the Fermi gas. Our results demonstrate a versatile route toward exploring quantum thermodynamics in strongly interacting many-body Fermi systems.

[1] Koch, J. et al. A quantum engine in the BEC-BCS crossover. Nature 621, 723-727 (2023)

Q 16.4 Tue 11:45 P 2

Observation of an integer quantum Hall state of six fermions — •Johannes Reiter, Paul Hill, Maciej Galka, and Selim Jochim — Physikalisches Institut, Univeristät Heidelberg, Deutschland

Integer and fractional quantum Hall states underpin the understanding of topological phases of matter featuring exotic macroscopic properties such as the quantization of the transverse resistivity and emergence of robust edge currents. Expanding upon our deterministic preparation of a spinful two-particle Laughlin state [PRL 133, 253401], we present the recent observation of an integer quantum Hall state of six rapidly rotating fermions confined in a tight optical tweezer. Momentum-space imaging of the many body density reveals the hallmark uniform flattening of the particle density distribution. Through a differential time-of-flight measurement in anisotropically shaped traps, we extract the 2D current density indicative of the non-zero angular momentum in quantum Hall states. This novel technique allows direct determination of the angular momentum otherwise impossible to obtain from a density measurement without prior assumptions of the state's composition.

Our results not only demonstrate the scalability of our atom-by-atom assembly technique of quantum hall states, but also introduce a new method to directly measure angular momentum, opening new avenues for probing the microscopic kinematics of topological phase transitions.

Q 16.5 Tue 12:00 P 2

Local shielding of ground state wavefunctions during imaging of lithium-6 — •Daniel Dux, Tobias Hammel, Maximilian Kaiser, Finn Lubenau, Tim Schiffer, Matthias Weidemüller, and Selim Jochim — Physikalisches Institut, Heidelberg, Germany

We present a technique to locally shield ^{6}Li atoms during spin-resolved fluorescence detection. By overlapping selected regions of the system with a laser beam tuned near the $2P \leftrightarrow 3S$ excited-state transition at 813 nm, we induce substantial light shifts of the D2 imaging transition due to the diverging polarizability close to the resonance. This shift strongly suppresses fluorescence from illuminated atoms while leaving the wavefunction unaffected, enabling selective shielding and thus local readout of the surrounding system.

We combine this shielding method with our novel free-space imaging scheme, which provides simultaneous, single-atom, spin-resolved detection. Together, these capabilities allow us to interrogate chosen subsets of the system while protecting others from measurement backaction. Integrating both modules into our modular experimental platform, the Heidelberg Quantum Architecture [1], we realize deterministically prepared few-body systems with programmable local readout.

[1]: T. Hammel, M. Kaiser, et al., Modular quantum gas platform, Phys. Rev. A **111**, 033314

Q 16.6 Tue 12:15 P 2

Ytterbium quantum gases under the microscope — •Philipp Lunt[1,2], Riccardo Panza[2], Sandra Sbernardori[2], Fabrizio Barbuio[2], Alessandro Muzi Falconi[2], Matteo Marinelli[2], and Francesco Scazza[2] — [1]Universität Heidelberg, Physikalisches Insitut, Im Neuenheimer Feld 226 — [2]ArQuS Laboratory, CNR Edificio Q2, Trieste, Italy

In this talk, I will present the realization of a single-atom resolved quantum gas of ultracold ytterbium atoms under the microscope. This system provides a unique platform for exploring fermionic quantum many-body physics at the single-atom level, featuring a long-lived metastable state ideal for coherent qubit encoding and the simulation of multi-orbital models. Central to this work is a fast, high-fidelity, and low-loss single-atom imaging technique that enables atom re-use in quantum processors and atomic clocks [1,2].

[1] O. Abdel Karim et al 2025 Quantum Sci. Technol. 10 045019 [2] A. Muzi Falconi et al https://arxiv.org/abs/2507.01011 (2025)

Q 16.7 Tue 12:30 P 2

Overcoming Atom Loss During Cooling Utilizing Two-Photon Repumping for Ytterbium — •Michael Huber[1,2], René Villela[1,2], Er Zu[1,2], Ronen Kroeze[1,2], and Monika Aidelsburger[1,2] — [1]Ludwig-Maximilians-Universität — [2]Max-Planck-Institut für Quantenoptik

Neutral ytterbium atoms provide a clock state pair whose precise state-dependent control enables a novel approach to quantum simulation and computation. Enhanced, state-selective control can be realized by leveraging magic and tune-out wavelengths. Additionally, these states enable direct access to the 3D ground state via resolved sideband cooling. However , imperfect repumping efficiency during cooling leads to a non-negligible population accumulating in the anti-trapped 3P2 state, causing losses. Here, we demonstrate a method to suppress this loss channel by implementing a coherent two-photon transition from 3P0 to 3P1. We report a laser-stabilization scheme in which we use a high finesse cavity transferring the stability from the clock laser to the two-photon-repumping lasers. This approach provides robust control of the repumping dynamics and substantially mitigates losses during ground state cooling.

Q 16.8 Tue 12:45 P 2

Bound state in the continuum realized in ultracold gases — •Eleonora Lippi, Alexander Guthmann, Louisa Marie Kienesberger, Felix Lang, and Artur Widera — Department of Physics and Research Center OPTIMAS, RPTU University Kaiserslautern-Landau, 67663 Kaiserslautern, Germany

Quantum mechanical interaction potentials typically support either bound molecular states or unbound scattering states. An interesting exception are bound states in the continuum (BICs), localized quantum states with energies well above the molecular dissociation threshold that have no wavefunction overlap with free scattering states. In 1985, Friedrich and Wintgen (FW) proposed a mechanism to realise such BICs in quantum systems through the interference of two Feshbach resonances. Although BICs have largely been realised in classical systems, an unambiguous quantum-mechanical realisation based on the FW mechanism has so far remained elusive. In this talk, we present our experimental observations of the FW-BIC in an ultracold Li-6 atomic gas. This is achieved through the interference of two tunable Feshbach resonances induced by Floquet engineering, implemented via strong magnetic-field modulation that generates additional Feshbach scattering resonances with controllable positions and widths [1]. We support our observation by full coupled-channel calculations. Additionally, by an effective non-Hermitian Hamiltonian, we interpret the state as a dark-scattering state, in analogy to electromagnetically-induced transparency.

[1] Guthmann, A. et al., Sci. Adv.11, eadw3856 (2025)

Q 17: Photonics and Biophotonics I

Time: Tuesday 11:00–13:00 Location: P 3

Q 17.1 Tue 11:00 P 3

Stable Optical Vortex Rings in Linear and Nonlinear Media — •Zhamila Kulchukova[1] and Andrey Surzhykov[1,2] — [1]Physikalisch-Technische Bundesanstalt, Bundesallee 100, D-38116 Braunschweig, Germany — [2]Institut für Mathematische Physik, Technische Universität Braunschweig, Mendelssohnstrasse 3, D-38106 Braunschweig, Germany

Vortex rings are fundamental to both classical and quantum physical systems, from turbulent fluids to BECs. In optics, vortex rings are quantized ring-shaped vortices with vanishing intensity at the core, appearing as threads of darkness tied into a loop. Studying the nature of optical vortex rings and ways of manipulating them opens novel avenues for applications of structured light, i.e. optical tweezers, and helps to uncover the underlying mechanisms of physical phenomena not yet fully understood, such as quantum turbulence and spontaneous knotting. In this talk, we theoretically investigate an experimentally accessible system that exhibits stable vortex rings in vacuum and in nonlinear (focusing and defocusing) Kerr media. We demonstrate that the rings are not destroyed by symmetry-breaking and nonlinear effects, but instead undergo topological transformations of varying complexity. Despite its simplicity, our system provides a useful framework to study optical vortex rings and their dynamics. Moreover, it can open new ways to investigate the fine structure of the light and its applications in light-matter interactions.

Q 17.2 Tue 11:15 P 3

Active Electrically Switchable Polymer Metasurfaces for Microscope Imaging Functionalities — •Dominik Ludescher[1], Leander Siegle[1], Robert Horvat[1], Jonas Herbig[1], Pavel Ruchka[1], Junqi Lu[2], Marcos A. Dahlem[2], Sabine Ludwigs[2], Mario Hentschel[1], and Harald Giessen[1] — [1]4th Physics Institute and Research Center SCoPE, University of Stuttgart, Germany — [2]IPOC - Functional Polymers, Institute of Polymer Chemistry, University of Stuttgart, Germany

Integrating dynamic functionalities into 3D-printed optical components has remained a major challenge, leaving printed optics limited to static behavior. Electrically tunable materials such as the conducting polymer PEDOT:PSS offer a promising route toward adaptive, and compact optoelectronic systems. A key bottleneck has been the high-resolution patterning of PEDOT:PSS. However, we recently introduced two direct nanofabrication strategies that overcome these limitations: electron-beam-induced solubility modulation, and laser-based patterning using the same systems employed for two-photon polymerization of optical resins. The latter method enables true nanoscale patterning and is fully compatible with 3D-printed micro-optics. Using these techniques, we present a versatile integration scheme in which tunable PEDOT:PSS structures are positioned either beneath or atop static 3D-printed elements. This hybrid platform enables voltage-controlled transitions between dark-field and bright-field operation at CMOS-compatible voltages from -2 V to +2 V. The approach establishes a robust foundation for future reconfigurable photonic components.

Q 17.3 Tue 11:30 P 3

Controlling quantum noise through programmable nonlinear optics — •Michael Horodynski[1,2], Jamison Sloan[3,4], Shiekh Udding[1], Yannick Salamin[1], Michael Birk[5], Pavel Sidorenko[5], Ido Kaminer[5], Marin Soljačić[1,3], and Nicholas Rivera[6,7] — [1]Department of Physics, Massachusetts Institute of Technology — [2]Photonics Institute, TU Wien — [3]Research Laboratory of Electronics, Massachusetts Institute of Technology — [4]E. L. Ginzton Laboratory, Stanford University — [5]Department of Electrical and Computer Engineering, Israel Institute of Technology — [6]Department of Physics, Harvard University — [7]School of Applied and Engineering Physics, Cornell University

Light fields are now routinely structured across many degrees of freedom (i.e., spatial, temporal, and spectral), enabling unprecedented control over their classical properties. Although light's quantum properties limit important applications such as communications, imaging, and spectroscopy, an approach to shape the quantum statistical properties of light, such as correlations and noise, is missing. Here, we show that combining wavefront shaping with optical nonlinearity offers an unprecedented degree of control over the classical and quantum properties of light simultaneously. In our experimental demonstration, we combine spatial light modulation with the nonlinear dynamics offered by a multimode fiber to focus a region of high intensity, yet low noise, at the output of the fiber. The fiber output has intensity noise 20 times lower than what is achievable by linear means, and is at the quantum shot-noise level despite a highly noisy input.

Q 17.4 Tue 11:45 P 3

Experimental implementation of thermalisation in a nonlinear non-Hermitian optical lattice — •Julia Görsch[1], Joshua Feis[1], Andrea Steinfurth[1], Sebastian Weidemann[1], Georgios G. Pyrialakos[2], Matthias Heinrich[1], Mercedeh Khajavikhan[2], Alexander Szameit[1], and Demetrios N. Christodoulides[2] — [1]Institute of Physics, University of Rostock, Rostock, Germany — [2]Ming Hsieh Department of Electrical and Computer Engineering, University of Southern California, Los Angeles, California, USA

Optical thermodynamics has emerged as an efficient framework for describing and predicting the dynamics of strongly multimode, nonlinear systems. Yet, in non-Hermitian settings, many of the theoretically predicted effects have remained experimentally unexplored. Here, we report the first experimental observation of thermalisation in a nonlinear, non-Hermitian optical lattice using a platform based on coupled optical fiber loops. This arrangement emulates light propagation in a one-dimensional lattice by coupling two fiber loops of unequal length via a beam splitter, thereby mapping pulse evolution onto a doubly discrete (1+1)D lattice. Within this system, we engineer a pseudo-Hermitian lattice whose non-Hermiticity arises from anisotropic nearest-neighbor coupling, implemented via a tunable beam-splitting ratio combined with amplitude modulation. Following excitation with a superposition of eigenmodes, the system undergoes a clear thermalisation process - despite its intrinsic non-Hermiticity - revealing a previously inaccessible regime of non-Hermitian optical thermodynamics and opening the door to further experimental investigations.

Q 17.5 Tue 12:00 P 3

Loss-Minimized Incoherent Photonic Computing on a Mach-Zehnder interferometer network — •Konrad Tschernig[1,2], Mingwei Yang[1,2], Felix Kübler[1], Okan Akyüz[1], Lennart Mannteuffel[1], Enrico Stoll[1], and Janik Wolters[1,2] — [1]Technical University of Berlin, Berlin, Germany. — [2]German Aerospace Center (DLR), Berlin, Germany.

We present an algorithm for loss-minimized incoherent photonic multiplication of N-dimensional vectors with $N \times N$ matrices on standard Clements Mach-Zehnder interferometer (MZI) meshes [1]. By applying arbitrary unitary transformations to incoherent light states, our method avoids phase control and additional MZI blocks required by the singular value decomposition in coherent schemes [2]. In comparison, the crossbar architecture [3] requires N times more optical energy than our scheme to perform the same $N \times N$ matrix-vector multiplication (MVM). Experimentally, we implement a 4×4 photonic MVM and demonstrate an optical convolutional neural network for MNIST classification. Utilizing our loss-minimized architecture, we aim to reduce the input intensity to the single photon regime to explore the limitations from shot noise.

[1] Clements, William R., et al., Optica 3.12 (2016): 1460-1465.
[2] Shen, Yichen, et al., Nature photonics 11.7 (2017): 441-446.
[3] Feldmann, Johannes, et al., Nature 589.7840 (2021): 52-58.

Q 17.6 Tue 12:15 P 3

Colloidal Self-Assembly for 3D Second-Harmonic Photonic Crystals — •Thomas Kainz[1], Ülle-Linda Talts[2], Helena Weigand[2], Rachel Grange[2], Ullrich Steiner[1], and Viola Vogler-Neuling[1] — [1]Adolphe Merkle Institute and NCCR Bioinspired Materials, University of Fribourg, CH-1700 Fribourg, Switzerland — [2]Institute for Quantum Electronics, Department of Physics, ETH Zürich, CH-8093 Zürich, Switzerland

Three-dimensional nonlinear (second-harmonic) photonic crystals can simultaneously generate different nonlinear processes. However, creating large crystals in all three dimensions presents a considerable challenge, primarily due to the chemical inertness of metal oxides. This study presents the first demonstration of colloidal-crystal templating into a second-order optical material. Self-assembled polystyrene opal templates are infiltrated with barium titanate sol-gel, resulting in an inverse fcc network of tetragonal barium titanate after calcination. Our samples have unprecedented sizes (>3000 unit cells in x, y directions and >100 in z) and reflectivity values above 80%. We engineered the final linear photonic bandgap and measured the second-harmonic generation (SHG) over it, including its intensity under polarization and its power dependence. We successfully replicated the photonic network into a second-order material and demonstrated, for the first time, a linear photonic band gap from a fully scalable three-dimensional photonic crystal made of a nonlinear optical material. We present the influence of a stopband on the SHG generation, with edge enhancement and inhibited spontaneous emission.

Q 17.7 Tue 12:30 P 3

Electric field-Induced second-harmonic generation in silicon-rich nitride — •Laurids Wardenberg, Krishna Koundinya Upadhyayula, and Jörg Schilling — Institut für Physik, Martin-Luther-Universität Halle-Wittenberg, Germany

Applying a DC electric field to PECVD-grown films of silicon-rich nitride enables a voltage-controllable second-order susceptibility, giving rise to electric field-induced second-harmonic generation (EFISH). From the quadratic scaling of the second-harmonic output with the applied field, both the field-dependent and field-free second-order susceptibilities are experimentally extracted, reaching values comparable to those of traditional nonlinear crystals. The associated third-order susceptibility is likewise obtained and shown to increase significantly with higher silicon content in the SiNx films.

To further boost the nonlinear response, a quasi-bound state in the continuum is excited by implementing an extended square 2D nanopillar array on a SiNx base layer. The resulting strong field confinement in this waveguide-like structure, combined with the field-free second-order nonlinearity, produces a pronounced enhancement of TM-polarized second-harmonic generation.

Finally, by applying a DC electric field parallel to the polarization of the pump in a similar resonant structure, the interaction between photonic resonances and the EFISH mechanism is demonstrated. Together, these results open the door to low-power, on-chip frequency-conversion applications using both second- and third-order nonlinearities of the CMOS-compatible silicon-rich nitride platform.

Q 17.8 Tue 12:45 P 3

Training nonlinear optical neural networks with Scattering Backpropagation — •Nicola Dal Cin[1,2], Florian Marquardt[1,2], and Clara Wanjura[1] — [1]Max Planck Institute for the Science of Light, Staudtstraße 2, 91058 Erlangen, Germany — [2]Department of Physics, University of Erlangen-Nuremberg, 91058 Erlangen, Germany

As deep learning applications continue to deploy increasingly large artificial neural networks, the associated high energy demands are creating a need for alternative neuromorphic approaches. Optics and photonics are particularly compelling platforms as they offer high speeds and energy efficiency. Neuromorphic systems based on nonlinear optics promise high expressivity with a minimal number of parameters. However, so far, there is no efficient and generic physics-based training method allowing us to extract gradients for the most general class of nonlinear optical systems. In this work, we present Scattering Backpropagation, an efficient method for experimentally measuring approximated gradients for nonlinear optical neural networks. Remarkably, our approach does not require a mathematical model of the physical nonlinearity, and only involves two scattering experiments to extract all gradient approximations. The estimation precision depends on the deviation from reciprocity. We successfully apply our method to well-known benchmarks such as XOR and MNIST. Scattering Backpropagation is widely applicable to existing state-of-the-art, scalable platforms, such as optics, microwave, and also extends to other physical platforms such as electrical circuits.

Q 18: Photon BEC

Time: Tuesday 11:00–13:00 Location: P 4

Q 18.1 Tue 11:00 P 4

Using Direct Laser Writing to fabricate potential landscapes for photon gases in dye-filled microcavities — Julian Schulz[1], Kirankumar Karkihalli Umesh[2], •Sven Enns[1], Niklas Caspar[1], Frank Vewinger[2], and Georg von Freymann[1,3] — [1]Department of Physics and Research Center OPTIMAS, RPTU Kaiserslautern-Landau, 67663 Kaiserslautern, Germany — [2]Institute of Applied Physics, University of Bonn, 53115 Bonn, Germany — [3]Fraunhofer Institute for Industrial Mathematics ITWM, 67663 Kaiserslautern, Germany

We experimentally investigate photon gases and photon Bose-Einstein condensates in dye-filled microcavities. In order to achieve condensation in 2D systems and to investigate further phenomena such as incoherent transport [1], the creation of potential landscapes for the photon gas is necessary. We use the 3D laser lithography technology called Direct Laser Writing (DLW) to fabricate these potentials. Thereby, polymer structures can be printed onto the surface of the cavity mirrors. The refractive index contrast between the polymer structures and the dye-solution inside of the cavity create potential landscapes due to the modified optical path length. Using DLW allows for the creation of higher trapping frequencies and coupling rates between single potential sites in comparison to other techniques. We demonstrate these advantages by showing measurements of the photon gas in a SHH-chain and the dimensional crossover from 2D to 1D [2].

[1] L. Garbe et al., SciPost Phys. 16, 029 (2024). [2] K. Karkihalli Umesh et al., Nature Physics 20, 1810-1815 (2024).

Q 18.2 Tue 11:15 P 4

Observation of critical scaling in the Bose gas universality class — •Leon Kleebank[1], Frank Vewinger[1], Arturo Camacho-Guardian[2], Victor Romero-Rochin[2], Rosario Paredes[2], Martin Weitz[1], and Julian Schmitt[3] — [1]Institute of Applied Physics, Bonn, Germany — [2]Instituto de Fisica, Mexico City,

Mexico — [3]Kirchhoff-Institut fur Physik, Heidelberg, Germany

Critical exponents characterize the divergent scaling of thermodynamic quantities near phase transitions and allow for the classification of physical systems into universality classes. While quantum gases thermalizing by interparticle interactions fall into the XY model universality class, the ideal Bose gas has been predicted to form a distinct universality class whose signatures have not yet been revealed experimentally. Here, we report the observation of critical scaling in a two-dimensional quantum gas of essentially noninteracting photons. We determine the critical exponent for the correlation length to be $\nu = 0.51(3)$.

Q 18.3 Tue 11:30 P 4

Kennard-Stepanov relation connecting absorption and emission in two-species xenon-noble gas mixtures — •Eric Boltersdorf, Thilo vom Hövel, Frank Vewinger, and Martin Weitz — Institute of Applied Physics, Bonn, Germany

Photons confined in a dye-filled microcavity can exhibit Bose-Einstein condensation upon thermalization through repeated absorption and (re-)emission processes on the dye molecules. This has been experimentally demonstrated for photons in the visible spectral regime in 2010. The most important prerequisite for the dye molecules to be a suitable thermalization mediator is the fulfillment of the so-called Kennard-Stepanov relation, a thermodynamic, Boltzmann-like scaling law connecting the absorption and emission lineshapes. In the present work, an experimental approach is investigated to realize Bose-Einstein condensation of vacuum-ultraviolet (100 nm - 200 nm; VUV) photons via repeated absorption and (re-)emission cycles between the $5p^6$ ground state and the $5p^5 6s$ (J = 1) excited state of xenon-noble gas excimer molecules in dense gaseous ensembles (pressure of up to 100 bar). Here, we present experimental data giving strong evidence for a Kennard-Stepanov scaling of photons in these dense xenon-noble gas ensembles.

Q 18.4 Tue 11:45 P 4

Limit Cycles Driven by non-Hermitian Interactions in Coupled Photon Condensates — •Kevin Peters[1], Peter Schnorrenberg[2], Daniel Ehrmanntraut[1,2], Nikolas Longen[1,2], and Julian Schmitt[2] — [1]Universität Bonn, Institut für Angewandte Physik, Wegelerstr. 8, 53115 Bonn, Germany — [2]Universität Heidelberg, Kirchhoff Institut für Physik, Im Neuenheimer Feld 227, 69120 Heidelberg

We report the first observation of limit cycle oscillations in photon condensates. In our experiments, photons were trapped in two coherently coupled, dye-filled optical microcavities forming a photonic dimer. Previous work has demonstrated Bose-Einstein condensation of the photons into the symmetric ground state of the dye-filled dimer above a critical photon number for the case of spatially uniform pumping. Here we report on the observation of emergent, self-sustained dynamics under inhomogeneous excitation. When only a single site of the dimer is pumped, we experimentally observe spontaneous oscillations in the photon number at both sites, appearing over a range of pump powers. We show that these oscillations are the result of stable limit cycles associated with a parametric instability predicted by theory. Unlike in Kerr and thermo-optical nonlinear cavities, the instability in the dye-microcavity system is driven by effective imaginary photon-photon interactions. These non-Hermitian interactions are mediated by the dye molecules, and their strength can be conveniently tuned via the cut-off frequency imposed by the cavity length.

Q 18.5 Tue 12:00 P 4

Two-Dimensional Photon Gases in a Silver-Mirror Based Optical Dye-Microcavity — •Niels Wolf, Leon Kleebank, Andreas Redmann, Frank Vewinger, and Martin Weitz — University of Bonn

While the thermalization of radiation through contact with matter is a well-established concept, it has been shown only relatively recently that, when applying this concept to low-dimensional photon gases, optical quantum gases with a tunable chemical potential can be realized, allowing for the formation of Bose-Einstein condensates of photons [1]. Thermalization is in this system reached by repeated absorption and emission processes on dye molecules, which act as a thermal reservoir for the photon gas. In principle one can expect that this photon gas thermalization mechanism should allow for a phase-space build-up of light, although microcavity systems based on dielectric mirrors have not shown this effect, as understood from the large angle-dependence of the dielectric mirror reflectivities, which result in photon loss [2]. We have set up a dye-filled microcavity apparatus based on metallic mirrors, which offer a much wider angular acceptance range than dielectric mirrors. The aim of this ongoing experiment is the observation of phase-space build-up of light. The current status of the experimental results, which include observations of the microcavity emission spectra of a two-dimensional photon gas in the metallic mirror setup, will be reported.

[1] J. Klaers, J. Schmitt, F. Vewinger, and M. Weitz, Nature 468, 545-548 (2010) [2] E. Busley et al., Phys. Rev. A 107, 052204 (2023)

Q 18.6 Tue 12:15 P 4

On vortices in photon Bose–Einstein condensates: Open-dissipative effects on size and stability — •Joshua Krauss and Axel Pelster — Physics Department and Research Center OPTIMAS, RPTU Kaiserslautern-Landau, Kaiserslautern, Germany

Open-dissipative quantum fluids have been extensively studied numerically [1,2]. In view of a complementary analytical description, a recent study [3] introduced the projection optimization method, generalizing the standard optimization method for closed condensates [4] to open-dissipative systems. We apply this method to a complex Gross–Pitaevskii equation [6] that heuristically models a photon Bose–Einstein condensate, which is harmonically trapped. Together with established methods from hydrodynamics, we obtain an approximate dynamical vortex solution and demonstrate how open-dissipative parameters affect vortex both size and stability.

[1] V.N. Gladilin and M. Wouters, *Phys. Rev. Lett.* **125**, 215301 (2020)
[2] V.N. Gladilin and M. Wouters, *New J. Phys.* **19**, 105005 (2017)
[3] J. Krauß *et alii*, *Phys. Rev. Res.* **7**, 033007 (2025)
[4] V.M. Perez-Garcia *et alii*, *Phys. Rev. Lett.* **77**, 5320 (1996)
[5] J. Keeling and N.G. Berloff, *Phys. Rev. Lett.* **100**, 250401 (2008)

Q 18.7 Tue 12:30 P 4

Steady-state behavior and symmetry breaking of photon BECs — •Milan Radonjić[1,2], Axel Pelster[3], and Michael Thorwart[1] — [1]I. Institut für Theoretische Physik, Universität Hamburg, Germany — [2]Institute of Physics Belgrade, University of Belgrade, Serbia — [3]Physics Department, Rheinland-Pfälzische Technische Universität Kaiserslautern-Landau, Germany

We revisit the dynamics of open, driven-dissipative photon Bose-Einstein condensates (phBECs) in a dye-filled microcavity using a cumulant expansion approach within the Lindblad formalism [1,2]. Motivated by a recent study [3], we extend our previous work [2] by considering, in addition to U(1)-invariant operator averages, the condensate amplitude and other U(1)-symmetry breaking amplitudes as non-zero. Specifically, we analyze the possible steady states of the dynamics using a method typically employed in laser theory. This allows us to critically examine the emergence of the ghost attractor and its impact on the long-time behavior of phBECs.

[1] P. Kirton and J. Keeling, Phys. Rev. Lett. 111, 100404 (2013).
[2] M. Radonjić et al., New J. Phys. 20, 055014 (2018).
[3] A. Abouelela et al., Phys. Rev. Lett. 135, 053402 (2025).

Q 18.8 Tue 12:45 P 4

Ring Potentials for Photons in Dye-Filled Optical Microcavities — •Patrick Gertz, Leon Kleebank, Andreas Redmann, Kirankumar Karkihalli Umesh, Frank Vewinger, and Martin Weitz — Institute for Applied Physics, University of Bonn, Wegelerstraße 8, 53111 Bonn

Nanostructured dye-filled optical microcavities permit the study of quantum gases of light, while allowing precise experimental control over dimensionality, shape of the energy landscape and coupling to reservoirs. This enables the investigation of novel states of matter both in and out of equilibrium.

Here we report on the experimental implementation of a quantum gas of photons confined to a ring-shaped potential within such a material-filled microcavity, where the trapping potential is provided by static nanostructures, achieved by controlled laser-induced delamination of the dielectric coating of one of the cavity mirrors. We have achieved quasi-1D, periodically closed confinement of photon gases in ring potentials and performed measurements of the spatial and spectral distributions. Also, we observe macroscopic ground state occupation, giving preliminary evidence for Bose-Einstein condensation of photons in the system.

Q 19: Quantum Technologies – Ion Traps

Time: Tuesday 11:00–13:00 Location: P 5

Q 19.1 Tue 11:00 P 5

OPEN-2QS: towards long observation timescales in trapped ion systems — •Larisa Thorne and Ferdinand Schmidt-Kaler — QUANTUM, Johannes Gutenberg University Mainz, Department of Physics, Staudingerweg 7, Germany

Current state-of-the-art quantum simulators are limited by their short observation times. The OPEN-2QS platform leverages the advantages of Rydberg ions [1] with those of Penning trap configurations [2] to allow significantly longer observation times, up to 7 orders of magnitude longer than microscopic timescales [3]. This will allow us to pursue fundamental research questions previously inaccessible, such as characterizing collective dynamics beyond the decoherence timescale, and exploring non-equilibrium phenomena, particularly those in open many-body quantum systems. In this presentation, I will give an overview of the R&D program at Mainz, including the design of a Penning trap suited to confinement of $^{40}Ca^{+}$ Rydberg ions, and updates on the status of the requisite cryogenic components.

[1] A. Mokhberi et al, Adv. Atom. Mol. Opt. Phys. Vol. 69, pp. 233-306 (2020)
[2] A. Polloreno et al, arXiv:2203.05196 (2022)
[3] C. Chen et al, Nature 616, 691 (2023)

Q 19.2 Tue 11:15 P 5

Trapped ion crystal setup for efficient recording of photon correlations — •Benjamin Zenz[1], Roman Rosenfeld[1], Corina Revora[3], Christian T. Schmiegelow[3], and Ferdinand Schmidt-Kaler[1,2] — [1]QUANTUM, Institut für Physik, 55128 Mainz, Germany — [2]Helmholtz-Institut Mainz, 55099 Mainz, Germany — [3]Departamento de Física, Buenos Aires, Argentina

Trapped ions provide an exceptionally well-controlled quantum system with truly identical particles confined in deep potentials and manipulated with extraordinary precision. Each ion acts as a single-photon emitter allowing us to investigate collective light*matter interactions at the most fundamental level. In the past, we observed interference in both first- and second-order photon correlation functions, revealing spin-textures [1], spatially dependent bunched and antibunched photon statistics [2], superradiance and subradiance as well as measurement induced entanglement [3].

In this talk, I present our new experimental platform which combines, a multisegmented trap for the versatile control of the emitter positions. Furthermore, the setup features high-numerical-aperture detection from opposite directions, enabling efficient exploration of spatiotemporal photon correlations emitted from ion crystals of 50 and more ions. I report the system characterization along recent data and sketch future experiments.

[1] Verde, et al. Phys. Rev. A; 112, 043719 (2025)
[2] Wolf, et al. Phys. Rev. Lett.; 124, 063603 (2020)
[3] Richter, et al. Phys. Rev. Research; 5, 013163 (2023)

Q 19.3 Tue 11:30 P 5

Framework for optimization of Paul trap design and control voltages for X-junction shuttling — •Andreas Conta, Ulrich Poschinger, Santiago Bogino, and Ferdinand Schmidt-Kaler — QUANTUM, Institut für Physik, Johannes Gutenberg-Universität Mainz

Trapped-ion quantum computing is a promising architecture for large-scale quantum computing. We aim to scale up the shuttling-based [1] approach. This requires complex multi-segmented traps that include junctions [2]. We present our comprehensive framework for optimization of trap designs and control voltages waveforms, with the goal of shuttling a linear crystals an X-junction. Commercially available tools are used to create parameterised models of traps and potentials of the electrodes. Our custom Segmented Ion Trap CONtrol System (SITCONS) then performs a multipole expansion, thereby enabling the calculation of control voltages using quadratic programming. We analyse the influence of different trap designs and electrode shapes on the shuttling through an X-junction.

[1] Ruster et al., Phys. Rev. A 90, 033410 (2014)
[2] Delaney et al., Phys. Rev. X 14, 041028 (2024)

Q 19.4 Tue 11:45 P 5

Characterization of a commercial 3D ion trap — •Martin Hesse[1], Ranjit K. Singh[1,2], Ole Ketterkat[1], Jannik Mattil[1], André P. Kulosa[1], Ulf Hinze[3], Nicolas Spethmann[1], and Tanja E. Mehlstäubler[1,2] — [1]Physikalisch-Technische Bundesanstalt (PTB), Braunschweig, Germany — [2]Leibniz Universität Hannover, Hannover, Germany — [3]Laser nanoFab GmbH, Hannover, Germany

The Quantum Technology Competence Center (QTZ) was established at the Physikalisch-Technische Bundesanstalt (PTB) to support German industry in transitioning quantum technology (QT) from research into application.

Ion traps have evolved from fundamental research objects to an industrial product for QT applications ranging from quantum sensing to quantum simulation and computation. Within the QTZ user facility "Ion Traps", we offer access to a testbed for the standardized characterization of ion traps from industry and academia.

Here, we report about the characterization of a commercial, segmented 3D Paul trap. The electrode chips are made of Rogers material. The assembled ion trap is contacted to a carrier board which contains flexible electronic SMD-based filters to suppress electromagnetic noise coupling to the ion. We present the ion trap characterization routines to run automated to ensure repeatable measurements, which is - aside a reproducible environment - the key essential for a standardized characterization of ion traps.

Q 19.5 Tue 12:00 P 5

Characterization of Inner Control Electrode Shapes for Multi-Layer Surface-Electrode Ion Traps — •Florian Ungerechts[1], Rodrigo Munoz[1], Janina Bätge[1], Masum Billah[1], Giorgio Zarantonello[1,2], and Christian Ospelkaus[1,3] — [1]Institut für Quantenoptik, Leibniz Universität Hannover — [2]QUDORA Technologies GmbH — [3]Physikalisch-Technische Bundesanstalt

Trapped ions are a leading platform for quantum information processing. Scalable architectures, such as the Quantum Charged Coupled Device (QCCD) architecture, enable all-to-all connectivity between atomic ion qubits in dedicated registers and can be implemented on microfabricated surface-electrode traps. The development of novel fabrication techniques over the past years has transformed the design of surface-electrode ion traps into increasingly complex multi-layer structures. Yet, the control electrodes remain mostly unchanged. For three-dimensional traps and single-layer surface traps, the control electrodes are rectangular due to geometrical constraints. However, this does not imply that it is the ideal shape for control electrodes in modern multi-layer surface traps. Thus, we compare various shapes for inner control electrodes and evaluate their performance in terms of ion shuttling and radial shim compensation.

Q 19.6 Tue 12:15 P 5

Enhancing Trapped Ion Quantum Processor Scalability via Integrated Photonics and Microwave Technology — •Mohammad Masum Billah[1,2], Florian Ungerechts[1], Rodrigo Munoz[1], Phil Nuschke[1], Janina Bätge[1], Axel Hoffmann[1,4], Giorgio Zarantonello[1,3], Celeste Torkzaban[1], and Christian Ospelkaus[1,2,5] — [1]Institut für Quantenoptik, Leibniz Universität Hannover — [2]Laboratorium für Nano- und Quantenengineering, Leibniz Universität Hannover — [3]QUDORA Technologies GmbH — [4]Institut für Hochfrequenztechnik und Funksysteme, Leibniz Universität Hannover — [5]Physikalisch- Technische Bundesanstalt

Scalability is a critical requirement for performing meaningful computations with trapped-ion quantum processors. Microfabricated surface-electrode ion traps have demonstrated considerable potential to implement the scalable Quantum Charged Coupled Device (QCCD) architecture. However, reliance on free-space laser delivery poses a substantial challenge to expanding these systems. In our research, we explore laser-free gate operations using oscillating microwave magnetic field gradient for chip-integration of the gate mechanism. To achieve comprehensive scalability, photonics integration is essential for delivering, preparation and detection light via optical waveguides and grating outcouplers directly from the trap surface. Our study focuses on optimizing the placement of integrated light sources considering key factors such as light polarization and phase, opto-electrical effects, impacts on the trapping potential, optical crosstalk, thus addressing key challenges

to facilitate scalable trapped-ion quantum computing.

Q 19.7 Tue 12:30 P 5

Advancements in ion trap quantum computing with multiple ion species — •David C. Stuhrmann[1], Sascha Agne[2], Najwa Al-Zaki[1], Erik Dunkel[1], Radhika Goyal[1], Tobias Pootz[1], Kevin Rempel[1], Celeste Torkzaban[1], and Christian Ospelkaus[1,2] — [1]Institut für Quantenoptik, Leibniz Universität Hannover, Welfengarten 1, 30167 Hannover, Germany — [2]Physikalisch Technische Bundesanstalt, Bundesallee 100, 38116 Braunschweig, Germany

In the context of scalable quantum computing hardware with high-fidelity qubits, surface electrode ion traps are one of the most promising platforms. The long coherence times and very high fidelities of hyperfine qubits have been demonstrated on small numbers of ions. The ongoing challenge lies in scaling up the systems in terms of size, a process which necessitates improvements in hardware, as well as in experimental techniques. Building on the expertise of our existing room temperature experiments with near field microwave qubit interactions we present the next generation of cryogenic experiments. Our upgraded laser systems and the use of multiple ion species (Beryllium, Calcium, Strontium) position us for the adoption of integrated optics and sympathetic cooling. New ion trap geometries can be efficiently evaluated and include the ability to shuttle ions to dedicated zones to raise the number of addressable ions. The subsequent step is to establish automated calibration and monitoring procedures to optimize the device's uptime and remote connectivity for future applications.

Q 19.8 Tue 12:45 P 5

Parallelising electronic qubit control for trapped-ion quantum computing — •Dougal Main, Jacopo Mosca Toba, Hannah Knaack, Susanna Todaro, Amy Hughes, Lukas Spiess, Justin Niedermayer, Clemens Matthiesen, Steven King, and Oxford Ionics team — Oxford Ionics, Oxford, United Kingdom

We present our vision for large-scale, parallel control of trapped-ion qubits using chip-integrated electric and magnetic fields. Our architecture enables efficient parallelisation of gate operations and shuttling of ions on a surface-electrode trap chip with junctions, implementing a quantum charge-coupled device that is scalable and high-fidelity at the same time. We outline how single- and two-qubit gates can be performed in parallel, and show data from demonstrator devices.

Q 20: QuanTour II – Multi-photon Effects & Entanglement

Inspired by QuanTour, the traveling quantum-dot light source, the sessions QuanTour I-V focus on the physics of quantum light generation in solid-state systems and applications in quantum networks.

Time: Tuesday 11:00–13:00 Location: P 7

Invited Talk Q 20.1 Tue 11:00 P 7

Entangled photons from GaAs quantum dots in tunable circular Bragg resonators — •Armando Rastelli — Institute of Semiconductor and Solid State Physics, Johannes Kepler University, Linz, Austria

Entanglement is one of the most fascinating phenomena in quantum physics and a key resource for quantum technologies. Different from probabilistic sources, Quantum Dots (QDs) can emit polarization entangled photon pairs with negligible probability of multi-pair emission using the biexciton-exciton radiative cascade.

To make such sources practical, it is important to maximize the degree of entanglement, brightness, maximum emission rate, photon indistinguishably, and to be able to fine-tune the wavelength of the emitted photons. Ideally, the source should fulfill these requirements even when operated at temperatures of 30-40 K, that are reachable with compact cryocoolers. Meeting this list of requirements on a single QD device is a formidable challenge.

In this presentation, we will present our contribution to the field by focusing on GaAs QDs embedded in strain- and electrically-tunable circular Bragg resonators (CBRs). By making use of the intrinsically short lifetimes of GaAs QDs, the Purcell enhancement in the CBRs, as well as coherent excitation schemes, we will discuss the feasiblity of practical and scalable sources of entangled photons based on QDs.

Q 20.2 Tue 11:30 P 7

Indistinguishable photons from a two-photon cascade — •Timon L. Baltisberger[1], Francesco Salusti[2], Mark R. Hogg[1], Malwina A. Marczak[1], Nils Heinisch[2], Sascha R. Valentin[3], Arne Ludwig[3], Stefan Schumacher[2], Klaus D. Jöns[2], and Richard J. Warburton[1] — [1]Department of Physics, University of Basel, Switzerland — [2]Department of Physics and Center for Optoelectronics and Photonics Paderborn (CeOPP), Paderborn University, Germany — [3]Lehrstuhl für angewandte Festkörperphysik, Ruhr-Universität Bochum, Germany

Two crucial aspects of photon-based quantum technologies are indistinguishability and entanglement, both giving rise to a wide range of non-classical effects. The biexciton → exciton → ground state (XX → X → GS) cascade in self-assembled semiconductor quantum dots can produce polarization-entangled photon pairs [1]. However, the cascaded emission of this ladder system leads to timing jitter in photon emission, translating to a reduced indistinguishability of photons from both transitions [2]. Using the Purcell-effect in an open microcavity [3] to accelerate one transition of the two-step-cascade, we manipulate the timing jitter of the emitted photons in-situ. Our results show excellent agreement between theory and experiments over a wide range of parameters, and the generation of photons with very high indistinguishabilities of 94±2% (XX) and 82±6% (X).

[1] N. Akopian *et al.* Phys. Rev. Lett. **96**, 130501 (2006)
[2] E. Schöll *et al.* Phys. Rev. Lett. **125**, 233605 (2020)
[3] N. Tomm *et al.* Nat. Nanotechnol. **16**, 399 (2021)

Q 20.3 Tue 11:45 P 7

Photon Number Coherence in Two Photon Excitation — •Yusuf Karli[1,2], Florian Kappe[2], René Schwarz[2], Doris Reiter[3], Vikas Remesh[2], and Gregor Weihs[2] — [1]University of Cambridge, UK — [2]Universität Innsbruck, Austria — [3]TU Dortmund, Germany

Semiconductor quantum dots are prime candidates for single-photon sources in quantum communication, yet the security of protocols such as Quantum Key Distribution (QKD) depends critically on the Photon Number Coherence (PNC) of the emitted state. We investigate the generation and control of PNC in GaAs quantum dots under resonant two-photon excitation regimes, comparing standard biexciton-exciton cascading with stimulated two-photon excitation. While standard TPE yields negligible PNC due to incoherent relaxation processes, we demonstrate that the stimulated scheme effectively preserves electronic coherence, enabling on-demand tuning of PNC from zero to maximum values simply by varying the excitation pulse area. This stimulated approach simultaneously enhances photon indistinguishability to 95% while maintaining high purity [1]. Furthermore, addressing the sensitivity of TPE to environmental fluctuations, we introduce a robust stimulated adiabatic rapid passage (sARP) scheme[2]. We show that sARP maintains stable, vanishing PNC even in the presence of power drifts, for tailoring photon statistics to the specific security requirements of advanced quantum network protocols[1, 2].

[1] Karli, Y. et al. npj Quantum Inf. 10, 17. [2] Karli, Y. et al. Appl. Phys. Lett. 125 (25)

Q 20.4 Tue 12:00 P 7

Challenges and Advances Toward Maximal Entanglement in Quantum Dot Emitters — •Francesco Basso Basset for the QD-E-QKD photon source-Collaboration — Department of Physics, Politecnico di Milano, Milan, Italy

Quantum dots have become established sources of highly polarization-entangled photons, aiming to overcome trade-offs between brightness and entanglement. Despite evidence of nearly dephasing-free operation, open questions remain on the practical limits. This talk recaps experiments identifying mechanisms that must be controlled to reach near-unity entanglement, including multipair emission from re-excitation, spin noise from hyperfine interactions, and challenges in cavity-integrated devices operated at high brightness and GHz rates.

First, we report evidence of a recently proposed limitation in the standard on-demand scheme, resonant two-photon excitation of the biexciton-exciton cascade. The effect, linked to the optical Stark shift, strengthens as emission overlaps the excitation pulse, calling for dedicated mitigation. Second, we examine an often overlooked degree of freedom: emission angle. Photon momentum and polarization are correlated, especially in microcavities, introducing which-path information that reduces polarization entanglement. A simple dipole-emission model captures the behavior and guides the design of structures that maximize extraction efficiency without compromising fidelity.

These results show that key aspects of quantum-emitter behavior remain unresolved, and it is still too early to set limits on the future role of this technology in quantum networks.

Q 20.5 Tue 12:15 P 7

Scalable quantum interference of photons from multiple quantum dots. — •Sheena Shaji[1], Suraj Goel[1], Julian Weircinski[1], Frederik Brooke Barnes[1], Moritz Cygorek[2], Antoine Borel[1], Natalia Herrera Valencia[1], Erik M. Gauger[1], Mehul Malik[1], and Brian D. Gerardot[1] — [1]Institute of Photonics and Quantum Sciences, Heriot-Watt University, Edinburgh EH14 4AS, United Kingdom — [2]Condensed Matter Theory, Technical University of Dortmund, 44227 Dortmund, Germany

Scaling semiconductor quantum dots as platform to provide many mutually indistinguishable emitters remain has been a challenge due to their random spatial distribution and spectral inhomogeneity. In this talk, I will present a method to overcome these challenges using spatial light modulators to deterministically excite multiple emitters on the same chip, and to route their emission into a desired collection mode by programming phase grating holograms on them. We investigate cooperative emission arising from path erasure between distant, indistinguishable emitters. The primary signature of multi-emitter quantum interference, the emergence of bunching at zero delay in an intensity correlation experiment, is used to characterize the inter-emitter indistinguishability and the degree of correlation. We demonstrate scalability of this interference from two to five spectrally degenerate quantum dots and further confirm inter-emitter indistinguishability through Hong-Ou-Mandel interference between two emitters. These results provide a pathway towards rapid characterization of multiple emitters and realization of programmable, photonic quantum circuits.

Q 20.6 Tue 12:30 P 7

Entanglement generation through multi-photon interference with deterministic single photons in the telecom C-Band — •Nico Hauser[1], Matthias Bayerbach[1], Jochen Kaupp[2], Yorick Reum[2], Giora Peniakov[2], Johannes Michl[2], Martin Kamp[2], Tobias Huber-Loyola[2], Andreas T. Pfenning[2], Sven Höfling[2], and Stefanie Barz[2] — [1]Universität Stuttgart, 70569 Stuttgart, Germany — [2]Julius-Maximilians-Universität, 97074 Würzburg, Germany

Multi-photon interference of highly indistinguishable single photons in the telecom C-band is a critical requirement for many quantum communication and quantum computation protocols. While quantum dot-based single-photon sources have been demonstrated to be a prime candidate for deterministic single-photon generation in the telecom C-band, the generation of entangled multi-photon states from C-band quantum dots remains an active area of research. Here, we present multi-photon interference experiments using symmetric N-port beam splitters for multi-partite entanglement generation. We combine a quantum dot emitting in the telecom C-band with an active demultiplexing scheme to deterministically separate consecutively emitted single photons and show the generation of genuine multi-photon entangled states using compact, fiber-based multiport interferometers.

Q 20.7 Tue 12:45 P 7

High-fidelity entangled photon pairs from a quantum-dot-based single-photon source — •Malwina A. Marczak[1], Timon L. Baltisberger[1], Mark R. Hogg[1], Spencer Johnson[2], Nathan Arnold[2], Benjamin Nussbaum[2], Sascha R. Valentin[3], Arne Ludwig[3], Paul Kwiat[2], and Richard J. Warburton[1] — [1]University of Basel, Klingelbergstrasse 82, 4056 Basel, Switzerland — [2]University of Illinois, 337 Loomis Laboratory, 1110 W. Green Street, Urbana IL 61801, USA — [3]Ruhr-Universität Bochum, Universitätsstrasse 150, 44780 Bochum, Germany

Entangled photon pairs are a ubiquitous resource in quantum technologies, used in quantum key distribution and quantum networking. For scalable quantum networks, pairs that are indistinguishable in all degrees of freedom are essential, as they enable high-fidelity entanglement swapping across network nodes. We demonstrate a high-fidelity source of "swappable" entangled photon pairs using a semiconductor quantum dot (QD) coupled to a tunable microcavity. By actively modulating the QD emission between orthogonal polarization states, delaying one path in a low-loss Herriott cell, and recombining the two on a balanced beam splitter, we generate entangled photon pairs with a fidelity of 96%. The photons are mutually indistinguishable, enabling efficient entanglement swapping, a crucial requirement for quantum repeaters. We identify and mitigate fidelity-limiting factors, achieving a maximum fidelity of 98.9% through time-resolved post-selection that suppresses residual multi-photon events concentrated near the excitation pulse.

Q 21: Quantum Computing and Simulation III

Time: Tuesday 11:00–13:00 Location: P 10

Invited Talk Q 21.1 Tue 11:00 P 10

Interfacing with Quantum Information Processors—From Readout to Control — •Benjamin Lienhard[1,2], Shivang Arora[1,2], Emily Guo[1,2], Priyanka Yashwantrao[1,2], Patryk Dabkowski[1,2,3], and Stefan Filipp[1,2] — [1]Technical University of Munich, Garching 85748, Germany — [2]Walther-Meißner-Institut, Garching 85748, Germany — [3]Zurich Instruments, 8005 Zürich, Switzerland

Balancing the effort required for controlling quantum systems—especially during characterization and calibration—is essential for making quantum computing practical. This effort must remain lightweight enough to track drifting system parameters, yet efficient enough to enable rapid recalibration. Although theoretical models offer valuable intuition, they often fail to capture the full complexity of real devices. Conversely, exhaustive system characterization can yield accurate numerical models, but it is typically too resource-intensive to scale. Model-free learning approaches provide a flexible, data-driven alternative; however, they also require substantial measurement overhead. As quantum processors continue to grow, these challenges intensify. In this presentation, I will introduce machine-learning-based protocols that we have developed to enhance superconducting qubit readout, as well as strategies for scalable calibration of large-scale quantum processors.

* funded through the EQuIPS Quantum Futur project from the Federal Ministry of Education and Research (BMBFTR) under funding number 13N17232.

Q 21.2 Tue 11:30 P 10

The sub-Riemannian geometry of measurement based quantum computation — •Lukas Hantzko — Institut für Theoretische Physik, Leibniz Universität Hannover, Hannover, Germany

The computational power of symmetry-protected phases of matter can be accessed through local measurements, but what is the most efficient way of doing so? In this work, we show that minimizing operational resources in measurement-based quantum computation (MBQC) on subsystem symmetric resource states amounts to solving a sub-Riemannian geodesic problem between the identity and the target logical unitary. This reveals a geometric structure underlying MBQC and offers a principled route to optimize quantum processing in computational phases. (arxiv:2508.17808)

Q 21.3 Tue 11:45 P 10

Can parity measurements be implemented for continuous quantum error correction? — •Anton Halaski and Christiane P. Koch — Freie Universität Berlin, Berlin, Germany

In time-continuous quantum error correction, required in computations with time-varying Hamiltonians, the commonly employed strong projective measurements for syndrome extraction are replaced by weak continuous measurements. These protocols rely on sufficiently strong and continuous multi-qubit parity measurements to extract the error syndromes. The implementation of such measurements is challenging since they require a perpetual three-body interaction between two qubits and a meter. Here we show that, for the circuit QED architecture, known parity measurement protocols destroy the information encoded in the qubits when used in continuous operation since it is impossible to protect both the logical subspace and the error subspace from measurement backaction at the same time. We find the failure to be rooted in the approximation of the three-body interaction by a sum over two-body interactions between meter and qubits. Our findings suggest that continuous quantum error correction is possible only for architectures based on erasure qubits, such as dual-rail encodings, where there is no need to protect the error subspace from measurement backaction.

Q 21.4 Tue 12:00 P 10

Sample-Based Krylov Quantum Diagonalization for the Schwinger Model on Trapped-Ion and Superconducting Quantum Processors — •Jurek Eisinger[1], Emil Rosanowski[2], Lena Funcke[2], Ulrich Poschinger[1], and Ferdinand Schmidt-Kaler[1] — [1]QUANTUM, University of Mainz, Department of Physics, Staudingerweg 7, Germany — [2]University of Bonn, Nussallee 14-16, 53115 Bonn, Germany

We apply the Sample-based Krylov Quantum Diagonalization (SKQD) method to lattice gauge theories, using the Schwinger model with a θ-term as a benchmark. SKQD approximates the ground state of a Hamiltonian, employing a hybrid quantum*classical approach: (i) constructing a Krylov space from bitstrings sampled from time-evolved quantum states, and (ii) classically diagonalizing the Hamiltonian within this subspace. We implement the algorithm on both, trapped-ion and superconducting quantum processors, and study the dependence of the ground-state energy and particle number on the value of the θ-term, accurately capturing the model*s phase structure. A striking advantage of SKQD is the substantial reduction of the effective Hilbert space, although the Krylov space dimension still scales exponentially with the system size. Thus, SKQD is a promising method for simulating lattice gauge theories in larger volumes. The methods and results are described in more detail in [Rosanowski et al., arXiv:2510.26951 (2025)].

Q 21.5 Tue 12:15 P 10

QCMobility: Quantum Computing & Mobility — •Matthias Zimmermann and the QCMobility-Team — Deutsches Zentrum für Luft- und Raumfahrt e.V. (DLR), Institute of Quantum Technologies, Ulm, Germany

This talk provides an overview of the project QCMobility [1] within the DLR Quantum Computing Initiative. Here, we explore application problems in mobility which might benefit from the usage of quantum computers. These include strategic and tactical planning processes in air transport, optimization problems in demand-driven traffic in road transport, planning and dispatching processes in rail transport, route and trajectory optimization in highly automated/autonomous systems in maritime transport, and optimization of multidimensional logistics networks in intermodal transport. In close collaboration with several contractors from industry and various DLR institutes, we aim at developing customized quantum algorithms and demonstration problems to implement them on quantum computing hardware. The project results will be incorporated into the Quantum Computing and Mobility application roadmap.

[1] https://qci.dlr.de/en/qcmobility/

Q 21.6 Tue 12:30 P 10

Truncated Wigner Approximation of Quantum annealing on large Graph instances — •Dennis Breu, Simon Ohler, and Michael Fleischhauer — Department of Physics and Research Center OPTIMAS, RPTU-University of Kaiserslautern-Landau, D-67663 Kaiserslautern, Germany

Solving NP-Hard problems like traveling salesman and Max-Cut are of great interest in industry, for example to optimise shipping routes and supply changes. Quantum Annealing (QA) algorithm is a contender to achieve quantum supremacy on near-term non fault-tolerant quantum computers for these kinds of problems. However, there is no mathematical proof for the quantum advantage and current experimental scales are too small to draw objective conclusions. Thus there is a need to better understand the behavior of QA on intermediate scales. To make larger system sizes computationally accessible we make use of the truncated Wigner approximation (TWA), a semi-classical approximation which, through Monte-Carlo sampling, takes lowest order quantum-fluctuations into account. With TWA it is possible to simulate several hundred spins and better quantify the scaling of the computational effort of QA with the system size than previous methods like ED. Preliminary results seem to indicate that the computational effort for QA on a quantum computer becomes exponential in the same cases where it does for state of the art algorithms on classical computers.

Q 21.7 Tue 12:45 P 10

Boosting Classification with Quantum-Inspired Augmentations — Matthias Tschöpe[1], Vitor Fortes Rey[1,2], Sogo Pierre Sanon[1], Paul Lukowicz[1,2], Nikolaos Palaiodimopoulos[1,2], and •Maximilian Kiefer-Emmanouilidis[1,2] — [1]DFKI Kaiserslautern — [2]RPTU Kaiserslautern-Landau

Small quantum gate perturbations, common in quantum hardware but absent in classical computing, are typically viewed as errors, yet they may serve as a form of data augmentation and offer advantages in quantum machine learning. In this work, we study random Bloch sphere rotations, fundamental SU(2) transformations, as a simple quantum-inspired augmentation method for classical image classification. Unlike standard techniques such as flipping or cropping, these transformations lack intuitive spatial interpretation. Rather than using quantum models or quanvolutional layers, we apply small-angle Bloch rotations directly to classical data and evaluate their effect. Experiments on the ImageNet dataset show consistent performance gains, including a 3% improvement in Top-1 accuracy, a 2.5% gain in Top-5 accuracy, and an increase in F1 score from 8% to 12% over standard augmentation pipelines. We also explore stronger unitary transformations, which produce visually unrecognizable images with potential relevance to privacy. However, we find no measurable improvements in differential privacy and discuss the implications.

Q 22: Nuclear and X-Ray Quantum Optics

Time: Tuesday 11:00–13:00 Location: P 11

Invited Talk Q 22.1 Tue 11:00 P 11

Exploring nonlinear optics with x-rays — •Dietrich Krebs — Deutsches Elektronen-Synchrotron DESY, Notkestr. 85, 22607 Hamburg, Germany

Using modern synchrotron and free-electron laser (FEL) sources, it has become feasible to study a wide range of nonlinear processes in the x-ray regime. With it comes the possibility to transfer ideas from parametric nonlinear optics as well as quantum optics to shorter wavelengths, for which we will explore examples in this talk. Processes of interest comprise x-ray-optical wavemixing (XOWM) that can combine diffractive imaging capabilities with spectroscopic sensitivity for new material diagnostics. As such, we have recently demonstrated the applicability of nonlinear crystallography using x-ray-optical difference-frequency generation to spatially reconstruct the valence response in diamond at sub-Angstrom resolution. Processes deriving from spontaneous x-ray parametric down-conversion (XPDC), on the other hand, can provide access to quantum features of light-matter interaction. As an example, we showcase a series of experiments, in which we found that non-degenerate XPDC allows access to polariton-formation in the extreme-ultraviolet (EUV) and soft x-ray spectral ranges. Recent developments have also shown renewed interest to extend XPDC into the degenerate regime, aiming to produce energetically equal x-ray photon pairs as a resource of entanglement. While these examples still face substantial challenges regarding their efficiency, they provide a promising outlook for the future of x-ray quantum optics.

Q 22.2 Tue 11:30 P 11

Nuclear excitation in ^{229}Th using paraxial light fields — •Tobias Kirschbaum, Janek Bergmeier, Alexander Franz, and Adriana Pálffy — Julius-Maximilians-Universität Würzburg, Germany

The paraxial wave equation (PWE) provides a variety of solutions depending on the specific geometry such as Laguerre Gaussian (cylindrical) and Hermite Gaussian modes (cartesian). Among others, these modes are characterized by their spatially inhomogeneous intensity profiles which render them attractive to atomic physics applications. For instance, such beams can be used in quantum metrology to minimize the unwanted light shift in atomic clock transitions [1, 2]. A compelling alternative for these atomic clocks is the ^{229}Th nucleus which has a long-lived first excited state at ≈ 8.4 eV [3]. It is thus intriguing to investigate the interaction of thorium with different paraxial light fields.

In a first step, we have investigated the interaction of ^{229}Th with non-paraxial and spatially inhomogeneous Bessel modes [4]. Here, we build upon that work by considering paraxial light fields which are also spatially inhomogeneous. We thereby address the temporal and spatial dynamics for ^{229}Th in solid-state and ion targets using solutions of the PWE in cylindrical, cartesian, and elliptical coordinates.

[1] R. Lange *et al.*, Phys. Rev. Lett. **129**, 253901 (2022).
[2] A. Peshkov *et al.*, Ann. Phys. **535**, 2300204 (2023).
[3] C. Zhang *et al.*, Nature **633**, 63-70 (2024).
[4] T. Kirschbaum *et al.*, Phys. Rev. C **110**, 064326 (2024).

Q 22.3 Tue 11:45 P 11

Coherent vortex pulse propagation in ^{229}Th:CaF$_2$ — •Alexander Franz, Tobias Kirschbaum, and Adriana Pálffy — Julius-Maximilians-Universität Würzburg, Am Hubland, 97074 Würzburg, Germany

In recent years, the isomeric transition in ^{229}Th has emerged as a promising candidate for the development of a nuclear clock [1]. One of the possible approaches for realizing such a clock involves embedding ^{229}Th nuclei into VUV-transparent crystals. In this work, we investigate from theoretical side the driving of the nuclear clock transition in ^{229}Th-doped crystals using Bessel beams, a form of light with helical wavefronts and spatial degrees of freedom. Due to the magnetic dipole character of the clock transition, such beams offer new control degrees of freedom compared to standard plane waves [2]. We study nuclear forward scattering of a resonant Bessel beam pulse propagating through the crystal, analyzing the resulting temporal and spatial intensity patterns. To this end, we extend an existing formalism developed for plane waves to Bessel beams [3]. We consider scenarios involving a single nuclear transition and multiple simultaneously driven transitions, as well as different orientations of the quantization axis. This approach opens a way to determine the relative distribution of different directions of quantization axes inside the crystal.

[1] C. Zhang *et al.*, Nature **633**, 63-70 (2024).
[2] T. Kirschbaum *et al.*, Phys. Rev. C **5**, 064326 (2024).
[3] Y. V. Shvyd'ko, Phys. Rev. B **59** 9132 (1999).

Q 22.4 Tue 12:00 P 11

Quantum dynamics of strongly-driven interacting Mössbauer nuclei — Miriam Gerharz[1], Dominik Lentrodt[1,2], and •Jörg Evers[1] — [1]Max-Planck-Institut für Kernphysik, Heidelberg — [2]Physikalisches Institut, Albert-Ludwigs-Universität Freiburg, Freiburg im Breisgau

It is an old challenge whether it is possible to fully excited an ensemble of atomic nuclei using externally applied electromagnetic fields. Motivated by recent progress in x-ray source technology and in nuclear quantum optics, in this talk, I will revisit this problem from two sides. First, I will discuss the prospects of non-linear excitation of nuclei in thin-film x-ray cavities using strongly focused x-ray pulses. To this end, we developed a comprehensive theory framework to model focused x-ray pulses in x-ray cavities, and derived the excitation enhancement via the optimization of the nuclear environment [1]. Second, I will discuss the many-body coupled dissipative dynamics of the nuclear ensemble after the excitation, using a cumulant expansion which allowed us to derive a set of nonlinear equations which is capable of efficiently modeling large nuclear ensembles for arbitrary degrees of excitation [2]. We identified a non-linear time-evolution of the nuclear dipole phase as an experimentally accessible signature for higher excitation. Our analysis further predicts finite-size effects in the nuclear dynamics of small ensembles as an interesting as-yet unexplored observable.

[1] D. Lentrodt, C. H. Keitel, and J. Evers, Phys. Rev. Lett. 135, 033801 (2025); Phys. Rev. A 112, 013711 (2025).
[2] M. Gerharz and J. Evers, arXiv:2510.00970 [quant-ph].

Q 22.5 Tue 12:15 P 11

Dynamics of x-ray waveguides in front-coupling geometry — •Julien Spitzlay[1], Hanns Zimmermann[1,2], and Adriana Pálffy[1] — [1]Julius-Maximilians-Universität Würzburg — [2]Universität der Bundeswehr München

Thin-film nanostructures containing multiple embedded layers of Mössbauer nuclei offer an intriguing platform for realizing quantum optics in the x-ray regime. These structures can be probed either in grazing-incidence or front-coupling geometry. The latter was recently demonstrated experimentally [1] and showed excellent agreement with the theoretical framework developed so far [2].

In this work, we extend this formalism to model the mesoscopic quantum dynamics of x-ray waveguides in front-coupling geometry, including configurations with multiple modes and several layers of resonant material. This approach enables the engineering of effective inter-nuclear couplings to realize hopping models [2], thereby opening the door to investigating topological photonic systems of greater complexity than achievable in grazing-incidence configurations [3].

[1] L. Lohse, et. al., Phys. Rev. Lett. 135, 053601 (2025)
[2] P. Andrejić, et. al., Phys. Rev. A 109, 063702 (2024)
[3] H. Zimmermann, et. al., arXiv:2506.10588 (2025)

Q 22.6 Tue 12:30 P 11

Exploring Topological Effects in Thin-Film X-Ray Cavities — •Hanns Zimmermann[1,2,3], Jonathan Sturm[1,3], Ion Cosma Fulga[3,4], Jeroen van den Brink[3,4], and Adriana Pálffy[1,3] — [1]Julius-Maximilians-Universität Würzburg — [2]Universität der Bundeswehr München — [3]Würzburg-Dresden Cluster of Excellence ct.qmat — [4]Leibniz Institute for Solid State and Materials Research Dresden

A promising platform for the quantum control of high-frequency photons are thin-film cavities, with one or several embedded layers of resonant nuclei such as ^{57}Fe with a Mössbauer transition at 14.4 keV. At grazing incidence, incoming x-rays couple evanescently to the cavity. In turn, the cavity field drives the nuclear transitions. The resulting nuclear response is well described by a recently-developed quantum optical model based on the electromagnetic Green's function [1].

Here, we investigate theoretically topological effects in special geometries of x-ray quantum emitters i.e. Mössbauer nuclei. We show that tailored nanostructures with multiple layers of Mössbauer nuclei can implement a non-Hermitian version of the Su-Schrieffer-Heeger (SSH) model [2]. By tuning the geometry of the structure, different topological phases can be realized. Our results demonstrate the existence of topological edge states whose presence can be identified in the x-ray reflectivity spectra or in resonant beam coupling geometry [3].

[1] X. Kong, et al. Phys. Rev. A 102, 033710 (2020)
[2] H. Zimmermann, et. al., arXiv:2506.10588 (2025)
[3] L.M. Lohse et. al., Phys. Rev. Lett. 135, 053601 (2025)

Q 22.7 Tue 12:45 P 11

Electron spectroscopy of the Mössbauer transition in 57Fe — •K Ravi[1], E Månsson[1], L Bocklage[1,2], S Velten[1], I Sergeev[1], M Seitz[1], S Rockenstein[1], D Schmitt[3], M Kovacev[3,4], F Calegari[1,2,5], R Röhlsberger[1,6], and A Trabattoni[1,3,4] — [1]CFEL, Hamburg — [2]CUI, Universität Hamburg — [3]Leibniz University Hannover — [4]Cluster of Excellence PhoenixD, Hannover — [5]Department of Physics, Universität Hamburg — [6]IOQ, FSU Jena

Electron dynamics govern how nuclei interact with their electronic environment. In 57Fe Mössbauer isotopes, internal-conversion electrons and Auger-Meitner emission offer a surface-sensitive alternative to fluorescence for probing electron-nuclear energy exchange. Using synchrotron excitation and time-of-flight detection at PETRA III, we resolve magnetic hyperfine splitting and nuclear inelastic spectra, establishing a nuclear-electronic spectroscopy of coupled nuclear, electronic, and phononic excitations.

Q 23: Cold Molecules (joint session MO/Q)

Time: Tuesday 11:00–13:15 Location: P 105

Invited Talk Q 23.1 Tue 11:00 P 105

Observation of diffraction oscillations and low-energy resonances in elastic collisions between He Rydberg atoms and HD molecules — •Arijit Das[1], Yufeng Wang[1], Karl Horn[1], Piotr Zuchowski[2], Julia Narevicius[1], and Edvardas Narevicius[1] — [1]Technische Universität Dortmund, Dortmund, Germany — [2]Nicolaus Copernicus University, Torun, Poland

Observation of shape and Feshbach resonances in low-energy ion-neutral collisions has been a long-standing goal, but such collisions at cold temperatures remain elusive because of the difficulty of controlling ion beams. While Feshbach resonances between ions and atoms have been observed using magnetically tunable interactions [1], Rydberg atoms offer a powerful platform for exploring quantum collision dynamics in ion-molecule systems. The Rydberg electron acts as a spectator, effectively shielding the ion core and enabling precise investigations of long-range interactions during ion core-molecule collisions.

In this work, we investigate elastic collisions between helium Rydberg atoms and HD molecules at cold temperatures using a merged-molecular-beam apparatus. Velocity-map images of scattered helium reveal pronounced diffraction oscillations linked to partial-wave contributions dominated by ion core-neutral interactions. By tuning the collision energy, we also observe a series of low-energy scattering resonances. These observations provide a new pathway for detecting low-energy ion-molecule resonances that have, until now, remained inaccessible.

(1) Weckesser, Pascal, et al. Nature, 600, 429-433 (2021).

Q 23.2 Tue 11:30 P 105

Surface collision and thermalisation of a laser-coolable molecule aluminium monofluoride — •Pulkit Kukreja, Lasse Rautenberg, Sebastian Kray, Gerard Meijer, and Sid Wright — Fritz-Haber-Institut der MPG, Faradayweg 4-6, 14195 Berlin

Until very recently, direct laser cooling of molecules has been restricted to reactive species with $^2\Sigma$ electronic ground states. These molecules are challenging to produce and have only been captured into a magneto-optical trap (MOT) from pulsed, cryogenically cooled molecular beam sources. These are rather complex, expensive, and difficult to operate reliably for long periods.

At the Fritz Haber Institute, we have now realised the first MOT of a spin-singlet molecule: aluminum monofluoride (AlF). AlF has high chemical stability compared to $^2\Sigma$ molecules, and can also be made efficiently at moderate temperatures ($\sim$ 900 K) in an oven. Remarkably, we observe that AlF can survive collisions with, and therefore thermalise to, room temperature vacuum walls of our experiments.

Here, we present the outcomes of single AlF-surface collisions on a camera via Doppler-sensitive laser-induced fluorescence. We observe that AlF undergoes trapping-desorption at surfaces, with complete rovibrational and translational thermalisation to the surface. The collision outcomes are highly surface-dependent, with polydimethylsiloxane (PDMS) coatings having a low sticking coefficient. Our results open a pathway to molecular MOTs loaded from compact and inexpensive beam sources and suggest that the technology employed in atomic vapour cells can be applied to a laser-coolable molecule.

Q 23.3 Tue 11:45 P 105

Decoding Feshbach resonances of Ne+HD+ reaction using ion-electron coincidence and merged beam techniques — •Yufeng Wang[1], Arijit Das[1], Baruch Margulis[2], Karl Horn[1,3], Meenu Upadhyay[4], Markus Meuwly[4], Christiane Koch[3], and Edvardas Narevicius[1] — [1]Technische Universität Dortmund — [2]National Institute of Standards and Technology — [3]Freie Universität Berlin — [4]University of Basel

Feshbach resonance in collisions is an interesting quantum effect. In AMO studies, Feshbach resonance is widely used to produce Feshbach molecules by tuning the magnetic field. In reaction dynamics studies, Feshbach resonances also play a critical role in influencing the scattering cross section. However, this important phenomenon remains unclear to us due to the difficulty of experimental measurement.

Here, we developed a new method to investigate the Feshbach resonance based on ion-electron coincidence measurements, starting with a cold collision that leads to Penning ionization.[1] This new method was applied to research on Feshbach resonances in the Ne and HD+ collision. Assisted by the merged-beam technique, we lowered the collision energy to 22 mK and realized a p-wave (l=1) scattering. Combined with the high-resolution velocity map imaging technique, more substructures were observed and assigned to the Feshbach resonances arising from different vibrational modes of Ne-HD+ by high-accuracy quantum calculations. This work deepens our understanding of the Feshbach resonances in scattering.

(1) Margulis, B. et al. Science 380,77-81(2023).

Q 23.4 Tue 12:00 P 105

Magneto-optical trapping of aluminum monofluoride — •Jionghao Cai[1], José Eduardo Padilla Castillo[1], Priyansh Agarwal[1], Pulkit Kukreja[1], Russell Thomas[1], Boris Sartakov[1], Stefan Truppe[2], Gerard Meijer[1], and Sidney Wright[1] — [1]Fritz-Haber-Institute, Berlin, Germany — [2]Imperial College London, London, UK

Ultracold polar molecules have aroused great interest for their applications in testing fundamental physics and chemistry. Whilst there has been considerable success in associating ultracold diatomic molecules from laser-cooled atoms, these species are weakly bound and scarce in nature. A complementary approach is to laser cool molecules directly. So far, all diatomic and polyatomic species loaded into a magneto-optical trap (MOT) are spin-doublet molecules, and therefore chemically reactive. Moreover, their electronic structure only supports simple optical cycling from the first rotationally excited ($N = 1$) level.

Recently, we demonstrated the first MOT of a molecule with a (spin-singlet) $X^1\Sigma^+$ electronic ground state, aluminum monofluoride (AlF). We can routinely trap 6×10^4 AlF molecules via the deep ultraviolet $A^1\Pi \leftarrow X^1\Sigma^+$ transition, and, different to spin-doublet molecules, can straightforwardly select different rotational levels in the MOT. In this talk, I will provide a status update for the AlF MOT experiments, investigations of potential loss channels in the cooling cycle, and prospects for further cooling and trapping.

Q 23.5 Tue 12:15 P 105

Colder collisions for cleaner tomography of Feshbach resonances between atoms and molecules — •Karl P. Horn[1,2], Arijit Das[1], Yufeng Wang[1], Julia Narevicius[1,4], Meenu Upadhyay[3], Baruch Margulis[4], Daniel M. Reich[2], Markus Meuwly[3], Christiane P. Koch[2], and Edvardas Narevicius[1,4] — [1]Technische Universität Dortmund — [2]Freie Universität Berlin — [3]University of Basel — [4]Weizmann Institute of Science

Fundamental quantum effects are investigated at the interface between theory and experiment. Foremost amongst these are Feshbach resonances - observed, for instance, in collisions between rare gas atoms and a dihydrogen molecule ions (and their isotopomers). By launching collisions using Penning ionisation, coincidence measurement can yield a tomographic picture between incoming and outgoing quantum states [1]. Ab initio calculations convoluted to match the experimental resolution demonstrate good agreement with these experiments.

Until now, resolving contributions to the spectra due to individual initial partial waves and Feshbach resonances has been beyond experimental limitations [2]. The latest experiments demonstrate sufficient resolution to resolve these features and thereby test the validity of high-quality potential energy surfaces. By utilising Feshbach resonances characteristic to individual electronic structure methods and basis sets, a systematic comparison can be made between experiment and different levels of theory.

(1) Baruch Margulis et al. Science 380,77-81(2023).
(2) Karl P. Horn et al. JPCL 16 (31), 7862-7867 (2025).

Q 23.6 Tue 12:30 P 105

Electric-field control of atom-molecule Feshbach resonances — •Mara Meyer zum Alten Borgloh, Jule Heier, Fritz von Gierke, Baraa Shammout, Eberhard Tiemann, Leon Karpa, and Silke Ospelkaus — Leibniz University Hannover

We present our latest results on collisions between $^{23}Na^{39}K$ molecules and ^{39}K atoms, where we successfully observe Feshbach resonances between these scattering partners. For the first time in comparable systems, we demonstrate the ability to control the position of these resonances using electric fields. This allows us to investigate the electric field dependence of bound trimer states and assign specific quantum numbers to these states.

Our observations highlight a significant influence of the potassium atom on the molecule, despite the weak binding of the trimer state, which can be attributed to hindered rotation. These findings represent a new step in controlling atom-molecule interactions in ultracold gases and offer valuable insights into the behavior of molecular systems under external fields.

Q 23.7 Tue 12:45 P 105

Theory and experiments towards laser cooling of NH — •Daniel Roesch — TU Dortmund, Germany

Laser cooling of atoms is a well-established technique to reach very low temperatures and to generate degenerate quantum gases. Due to their more complex internal structure, molecules are much harder to laser cool. However, laser cooling of CaF, SrF, YO, YbF, BaF, AlF and SrOH has already been demonstrated and many other molecules are currently under investigation. We are working on laser cooling of ^{15}NH. This is a challenging molecule for laser cooling. While its light mass and cooling transition in the UV give rise to large momentum transfer for each absorbed photon, a long lifetime of the excited state and resulting narrow transition are posing considerable challenges. I will present results of hyperfine state resolved laser-induced fluorescence experiments on the cooling transition $A^3\Pi_0 \leftarrow X^3\Sigma^-$ for ^{15}NH as well as high resolution THz spectroscopy probing the $X^3\Sigma^-, N = 1 \leftarrow X^3\Sigma^-, N = 0$ rotational transition in the ground state. In addition to the experimental spectroscopy results I will also present results from laser cooling simulations using the pyLCP python package and machine learning optimization of laser cooling parameters.

Q 23.8 Tue 13:00 P 105

Towards a Dipolar BCS-BEC Crossover — •Eugen Dizer[1], Arthur Christianen[2], Xin Chen[1], and Richard Schmidt[1] — [1]Institut für Theoretische Physik, Universität Heidelberg, 69120 Heidelberg, Germany — [2]Institute for Theoretical Physics, ETH Zürich, Zürich, Switzerland

Dipolar Fermi gases are expected to show exotic phases of matter, such as the supersolid and the Wigner crystal phase. Their anisotropic long-range interactions make them also highly relevant for the study of unconventional superconductivity. In this work, we focus on the case of highly population-imbalanced dipolar Fermi gases to explore their few- and many-body physics. We analyze the quantum scattering of a single impurity in a dipolar Fermi sea, highlighting key differences from conventional short-range interaction models. Additionally, we discuss implications for the polaron-to-molecule transition and Anderson's orthogonality catastrophe, introducing a new theoretical framework to address this problem. Our results provide insights into the interplay between s- and p-wave pairing, and the emergence of supersolid phases, in the dipolar BCS-BEC crossover. We propose an experimental protocol to test the predictions in this work using ultracold molecules.

Q 24: Ultra-cold Atoms, Ions and BEC I (joint session A/Q)

Time: Tuesday 11:00–13:00 Location: N 1

Q 24.1 Tue 11:00 N 1

Dark-state semi-localization and subradiance in dissipative systems — •Raphaël Menu, Thomas Botzung, and Johannes Schachenmayer — CESQ/ISIS, Université de Strasbourg, Strasbourg, France

Since their discovery, hybrid states of light and matter have sparked bustling interest across diverse fields, ranging from condensed matter physics and atomic physics to chemistry. While "bright" states are largely unaffected by disorder, it has been demonstrated that strong light-matter coupling gives rise to unconventional localization behavior in "dark" light-matter states [1,2]. This phenomenon, coined as semi-localization, has been theoretically evidenced in ensembles of quantum emitters with randomly distributed transition frequencies coupled to a single-mode cavity. However, for meaningful comparison with experimental realizations, a proper description of semi-localization must account for cavity losses and spontaneous emission. In this work, we assess the feasibility of observing semi-localization as a transient phenomenon under experimental conditions [3]. We explore the robustness of this phenomenon in dissipative systems using experimentally accessible figures of merit, and investigate the relation between subradiance and localization phenomena.

[1] T. Botzung & al. Phys. Rev. B 102, 144202 (2020)
[2] J. Dubail & al. Phys. Rev. A 105, 023714 (2022)
[3] M. Baghdad & al, arXiv:2208.12088 (2022)

Q 24.2 Tue 11:15 N 1

Mass-Gap Description of Heavy Impurities in Fermi Gases — Xin Chen, •Eugen Dizer, Emilio Ramos Rodríguez, and Richard Schmidt — Institut für Theoretische Physik, Universität Heidelberg, 69120 Heidelberg, Germany

Single impurities immersed in a degenerate Fermi gas exhibit fascinating many-body phenomena, such as the polaron-to-molecule transition and Anderson's orthogonality catastrophe (OC). It is known that mobile impurities of finite mass can be described as quasiparticles, so called Fermi polarons. In contrast, Anderson showed in 1967 that the ground state of a static, infinitely heavy impurity in a Fermi sea is orthogonal to the ground state of the system without impurity - a hallmark of the OC and a fundamentally non-perturbative effect. As a result, conventional variational approaches or path integral methods fail to capture this phenomenon accurately. Despite decades of research, a unified approach connecting the quasiparticle description of Fermi polarons with Anderson's OC has remained elusive. In this work, we present a theoretical framework for arbitrary-mass impurities in a Fermi sea that incorporates Anderson's OC, the polaron-to-molecule transition and the quasiparticle picture. Our theory provides a simple yet powerful description of interacting quantum systems, with broad implications for ultracold atom experiments, atomically thin semiconductors, and future studies of strongly correlated matter. Phys. Rev. Lett. 135, 193401 (2025).

Q 24.3 Tue 11:30 N 1

Quantum doubles in symmetric blockade structures — •Simon Fell — Institute for Theoretical Physics III, University of Stuttgart

Exactly solvable models of topologically ordered phases with non-abelian anyons typically require complicated many-body interactions which do not naturally appear in nature. This motivates the "inverse problem" of quantum many-body physics: given microscopic systems with experimentally realistic two-body interactions, how to design a Hamiltonian that realizes a desired topological phase? We solve this problem on a platform motivated by Rydberg atoms, where elementary two-level systems couple via simple blockade interactions. Within this framework, we construct Hamiltonians that realize topological orders described by non-abelian quantum double models. We analytically prove the existence of topological order in the ground state, and present efficient schemes to prepare these states. We also introduce protocols for the controlled adiabatic braiding of anyonic excitations to probe their non-abelian statistics. Our construction is generic and applies to quantum doubles $\mathcal{D}(G)$ for arbitrary finite groups G. We illustrate braiding for the simplest non-abelian quantum double $\mathcal{D}(S_3)$.

Q 24.4 Tue 11:45 N 1

Paramagnetic Phases of Strongly Correlated Lattice Fermions with Cavity-Mediated Long-Range Interactions — •Renan da Silva Souza, Youjiang Xu, and Walter Hofstetter — Goethe-Universität, Institut für Theoretische Physik, 60438 Frankfurt am Main, Germany

We investigated the steady-state paramagnetic phases of a Fermi-Hubbard model on a square lattice coupled to a transversely pumped optical cavity, using real-space dynamical mean-field theory (RDMFT) [1]. The cavity mediates long-range interactions [2] which compete with the onsite Hubbard interactions. This system exhibits a transition into a superradiant checkerboard density-wave (DW) phase with finite occupation imbalance. At quarter filling, we find that increasing temperature leads to the crystallization of a homogeneous Fermi-liquid (FL) phase into a DW phase. At half filling, we find regions of metastability between different RDMFT solutions where the occupation imbalance shows a hysteretic behavior characteristic of first order phase transitions. In those regions, the DW solution coexists with either the homogeneous FL or the Mott insulating solution. We obtain the thermodynamic phase transition by comparing the energies of the different solutions in the region of metastability.

[1] M. Snoek et al. NJP 10, 093008 (2008)
[2] V. Helson et al. Nature 618, 716-720 (2023)

Q 24.5 Tue 12:00 N 1

Topological Order in Symmetric Blockade Structures — •Tobias Florian Maier, Hans Peter Büchler, and Nicolai Lang — Institute for Theoretical Physics III and Center for Integrated Quantum Science and Technology, University of Stuttgart, 70550 Stuttgart, Germany

The bottom-up design of strongly interacting quantum materials with prescribed ground-state properties is a highly nontrivial task, especially if only simple constituents with realistic two-body interactions are available on the microscopic level. We study two- and three-dimensional structures of two-level systems that interact via a simple blockade potential in the presence of a coherent coupling between the two states. For such strongly interacting quantum many-body systems, we introduce the concept of blockade graph automorphisms to construct symmetric blockade structures with strong quantum fluctuations that lead to equal-weight superpositions of tailored states. Drawing from these results, we design a quasi two-dimensional periodic quantum system that – as we show rigorously – features a topological $\mathbb{Z}_2$ spin liquid as its ground state. Our construction is based on the implementation of a local symmetry on the microscopic level in a system with only two-body interactions [1].

[1] T. F. Maier, H. P. Büchler and N.Lang, *Topological Order in Symmetric Blockade Structures*, PRX Quantum **6**(3) (2025), doi:10.1103/dtlf-2q82.

Q 24.6 Tue 12:15 N 1

Spin and density order of ultracold two-component fermions coupled to an optical cavity — •Daniel Samoylov, Renan da Silva Souza, Youjiang Xu, and Walter Hofstetter — Goethe Universität, Institut für Theoretische Physik, 60438 Frankfurt, Germany

Ultracold two-component fermions coupled to a transversely pumped optical cavity experience cavity-mediated long-range interactions [1]. In the dispersive regime, when confined to a two-dimensional static optical lattice the steady states of this system can be described by an extended Hubbard Hamiltonian with long-range interactions mediated by the cavity photons. We use real-space dynamical mean-field theory (RDMFT) [2] to study the phase diagram of this system. We investigate the competition of the (superradiant) checkerboard density-wave (DW) phase and the magnetically ordered spin-density-wave (SDW) phase at half filling. For small values of the Hubbard onsite interaction strength and the cavity-mediated long-range interaction strength we find a homogeneous paramagnetic phase. The full phase diagram of the system is obtained by varying the Hubbard onsite interaction strength and the cavity-mediated long-range interaction strength at a fixed low temperature. We identify a region of coexistence between the DW and SDW solutions obtained within RDMFT. The thermodynamic phase transition in this region is obtained by comparing the energies of the different RDMFT solutions.

[1] K. Roux et al., Nat. Commun., 11, 1, 2974 (2020)
[2] M. Snoek et al., New J. Phys. 10, 093008 (2008)

Q 24.7 Tue 12:30 N 1

Towards stable, strongly dipolar mixtures of ultracold dysprosium atoms — •Marian Dürbeck, Lennard Reihs, Johannes Seifert, Bala Choudhari, Juan Pablo Marulanda Serna, Nelson Werum, Marco De Pas, Gerard Meijer, and Giacomo Valtolina — Fritz-Haber-Institut der Max-Planck-Gesellschaft, Faradayweg 4-6, 14195 Berlin

Quantum gases of magnetic atoms, such as dysprosium (Dy), have recently enabled the realization of the long-sought-after supersolid phase. More exotic regimes of supersolidity have been predicted for mixtures of these magnetic atoms. We report on our efforts to create stable mixtures of Dy. We show a broadly applicable frequency-modulation scheme for simultaneously slowing and trapping different isotopes of Dy and discuss progress in creating strongly dipolar Bose-Bose mixtures.

Q 24.8 Tue 12:45 N 1

Collective excitations in Quantum Bubbles — •Timothé Estrampes[1,2], Brendan Rhyno[1], Charles Garcion[1], Ernst M. Rasel[1], Éric Charron[2], and Naceur Gaaloul[1] — [1]Leibniz University Hannover, Institut für Quantenoptik, Germany — [2]Université Paris-Saclay, CNRS, Institut des Sciences Moléculaires d'Orsay, France

The realization of the first quantum bubbles, both in microgravity using radiofrequency dressing (Nature 606, 281-286 (2022)) and on the ground with quantum mixtures (PRL 129, 243402 (2022)), has opened the way to studying the evolution of condensed atoms in non-trivial geometries. Among these, collective excitation modes are of particular interest, as they are readily accessible experimentally. It has been shown that, during the transition from a filled to a hollow geometry, the behavior of excitation modes is non-monotonic. In this work, we investigate the behavior of collective excitations in quantum bubbles and search for potential thermodynamic signatures of the hollowing transition.

Q 25: Precision Spectroscopy of Atoms and Ions II (joint session A/Q)

Time: Tuesday 11:00–13:00 Location: N 3

Invited Talk Q 25.1 Tue 11:00 N 3

Stringent Tests of the Standard Model via High-Precision Measurements at ALPHATRAP — •Fabian Heisse[1], Matthew Bohman[1], Luca Geissler[1], Anton Gramberg[1], Philipp Justus[1], Charlotte König[1], Ivan Kortunov[2], Jialin Liu[1], Jonathan Morgner[1], Jacob Schrader[1], Victor Vogt[2], Stephan Schiller[2], Sven Sturm[1], and Klaus Blaum[1] — [1]Max-Planck-Institut für Kernphysik, Heidelberg — [2]Institut für Experimentalphysik, Univ. Düsseldorf, Düsseldorf

The Standard Model describes a broad range of physical phenomena but remains incomplete. Therefore, it is of utmost importance to verify its foundational theories in all their facets. The ALPHATRAP experiment is a dedicated cryogenic Penning-trap apparatus, designed for this exact purpose [1]. It enables measurements of bound electron g-factors ranging from light molecular hydrogen ions to heavy highly charged ions using non-destructive single ion spectroscopy techniques.

I will present the measurements of the bound electron g-factor in H-like, Li-like, and B-like tin ions ($Z = 50$) with 0.5 parts-per-billion precision. There, extreme electric field strength up to 10^{15} V/cm act on the electron, magnifying QED effects and allowing to test them via the comparison with theory [2]. Finally, I will show the results of the hyperfine microwave and rovibrational laser spectroscopy of the HD^+ ion [3]. These are essential for future matter-antimatter comparisons.

[1] Sturm *et al.*, Eur. Phys. J. Spec. Top. **227**, 1425 (2019).
[2] Morgner *et al.*, Nature **622**, 5357 (2023).
[3] König *et al.*, Phys. Rev. Lett. **134**, 163001 (2025).

Q 25.2 Tue 11:30 N 3

Doppler-free two-photon spectroscopy of xenon — •Björn-Benny Bauer[2,1], Felix Waldherr[1], Thorsten Groh[1], Skyler Degenkolb[2], and Simon Stellmer[1] — [1]University Bonn, Germany — [2]University Heidelberg, Germany

High-precision spectroscopy of xenon is essential for a range of applications, including electric dipole moment (EDM) searches and isotope-shift studies, but suitable high-power deep-UV laser sources remain difficult to access. Here, we present high-resolution, Doppler-free two-photon spectroscopy of xenon using fluorescence detection. From these measurements, we determine the isotope shifts and extract the hyperfine structure parameters of the targeted transition. We further perform a King-plot analysis incorporating electronically similar transitions. The results exhibit clear linearity among the bosonic isotopes, while pronounced non-linearities arise when fermionic isotopes are included.

Q 25.3 Tue 11:45 N 3

Precision X-Ray Spectroscopy of Kα transitions in He-like Uranium using Metallic Magnetic Calorimeter Detectors

— •Daniel A. Schnauss-Müller[1,2,3], Johanna H. Walch[1,2,3], Philip Pfäfflein[1,2,3], Marc O. Herdrich[1,2], Michael Lestinsky[2], Daniel Hengstler[4], Andreas Fleischmann[4], Christian Enss[4], Günter Weber[1,2], and Thomas Stöhlker[1,2] — [1]Helmholtz Institut, Jena — [2]GSI, Darmstadt — [3]Friedrich-Schiller-Universität, Jena — [4]Kirchhoff Institut, Heidelberg

He-like ions, as the simplest atomic multibody system, provide a unique testing ground for the interplay of the effects of electron-electron correlations and quantum electrodynamics (QED). Of particular interest are heavy highly charged systems, where inner shell electrons are exposed to extremely high field strengths. For L to K-transitions, experiments with ions at nuclear charge states Z > 54 where not available until now. Two X-ray spectroscopy studies of He-like uranium ions have been performed at the electron cooler of the storage ring CRYRING@ESR at GSI Darmstadt, using novel detectors of the maXs series, developed within the SPARC collaboration. Those detectors are able to measure photons from a few keV up to over 100 keV allowing the simultaneous investigation of Balmer-like and Kα transitions. The achieved spectral resolution of better than 90 eV at X-ray energies close to 100 keV reveals the substructure of the Kα1 and Kα2 lines for the first time. The result of this experiment and the first insights of a rerun this year are presented in the talk.

Q 25.4 Tue 12:00 N 3

Advances in the investigation of atomic transitions in Lr — •Elisabeth Rickert for the Lawrencium Collaboration-Collaboration — GSI Helmholtzzentrum für Schwerionenforschung GmbH, Darmstadt, Germany — Hemholtz-Institut, Mainz, Germany — Johannes Gutenberg-Universität, Mainz,Germany

The investigation of the atomic level structure of the heaviest elements is experimentally and theoretically challenging. The electric shell structure of transfermium elements is strongly influenced by relativistic effects, which significantly complicates theoretical predictions. Experimentally, atomic levels are largely unknown for $Z > 100$, whereby low production cross sections and short half-lives demand a tailored approach for laser spectroscopy on single-atom-at-a-time quantities. The RAdiation Detection Resonance Ionization Spectroscopy (RADRIS) technique has been successfully applied for the atomic level search in nobelium (No, $Z = 102$). In recent years, the RADRIS setup has been adapted to investigate the atomic structure of lawrencium (Lr, $Z = 103$). The two strongest ground-state transitions have been theoretically predicted in the regions around 20420 cm^{-1} ($^2S_{1/2}$) and 28500 cm^{-1} ($^2D_{3/2}$ state). In 2020 and 2022, over 800 cm^{-1} and 700 cm^{-1} have been scanned around the predicted transition wavenumber in the visible and uv range, respectively. So far, no transition could be detected, but 35% of the anticipated uncertainty of the theoretical predictions is still to be investigated. In the contribution, the status of the experiment and the data analysis will be presented.

Q 25.5 Tue 12:15 N 3

Measurement of the hyperfine structure of the $4f^{14}5d$: $^2D_{5/2}$ state in trapped ^{173}Yb$^+$ ions — •Rohan Chakravarthy[1], Jialiang Yu[1], Ikbal A. Biswas[1], Anand Prakash[2], Clara Zyskind[1], and Tanja E. Mehlstäubler[1,2] — [1]PTB, Germany — [2]LUH, Germany

We report a measurement of the hyperfine structure of the $4f^{14}5d$: $^2D_{5/2}$ state in ^{173}Yb$^+$ using the $4f^{14}6s$: $^2S_{1/2} \rightarrow 4f^{14}5d$: $^2D_{5/2}$ electric quadrupole (E2) transition at 411 nm in trapped ^{173}Yb$^+$ ions and the resolution of the higher order hyperfine structure C coefficient. The measurement involves coherent excitation of the atom with an ultrastable laser to the excited hyperfine states and the measurement of the absolute frequency of the transitions with a frequency comb referenced to an ultrastable silicon cavity and a hydrogen maser. This measurement, along with the planned measurement of the hyperfine structure of the $4f^{13}6s^2$: $^2F_{7/2}$ state will lead to the resolution of the higher order nuclear moments predicted in Yb.

Q 25.6 Tue 12:30 N 3

Two-Dimensional Magneto-Optical Trap as a Cold Atomic Beam Source for High-Precision Spectroscopy on Lithium — •Gregor Schwendler, Tim Redelbach, Hannah Jost, and Randolf Pohl — Johannes Gutenberg-Universität Mainz, QUANTUM, Institut für Physik & Exzellenzcluster PRISMA$^+$, Mainz, Germany.

Lithium is of great interest in atomic and nuclear physics studies. The determination of the isotope shift from spectroscopy of the D-lines has shown inconsistencies, which could be partially explained by quantum interference effects.[1] We aim to further reduce systematic uncertainties in the spectroscopy by using a cold atomic beam extracted from a high-flux two-dimensional magneto-optical trap[2], which drastically reduces the first-order Doppler shift. Additionally, the use of an active fiber-based retroreflector[3] further suppresses systematics by producing retracing wavefronts in the spectroscopy beam. Our cold atomic beam provides an atomic flux on the order of 10^9 atoms/s, sufficient for high-precision spectroscopy, and a tunable mean velocity in the range of 50 to 100 m/s. I will report on the current results and the status of the experiment.

[1] Brown et al., *Physical Review A* 87.3 (2013), p. 032504.
[2] Tiecke et al., *Physical Review A* 80.1 (2009), p. 013409.
[3] Beyer et al., *Optics Express* 24.15 (2016), p. 17470.

Q 25.7 Tue 12:45 N 3

Cold Hydrogen Beam Source for Magnetic Trapping of Atomic Hydrogen — •Merten Heppener and Randolf Pohl — Johannes Gutenberg-Universität Mainz, QUANTUM, Institut für Physik & Exzellenzcluster PRISMA++ , Mainz, Germany

We are currently setting up an experiment to determine the root-mean-square triton charge radius via two-photon 1S-2S laser spectroscopy at 243 nm on magnetically trapped tritium atoms [1]. For preparation of trapping, a cold atomic hydrogen source consisting of a microwave discharge and a cryogenic nozzle was set up. The atom beam was characterized using time-of-flight techniques, the results of which we will present here. A velocity filter in form of a magnetic quadrupole guide will be installed shortly to further reduce the beam velocity. After achieving a stable atomic hydrogen beam, the 243 nm laser system and enhancement cavity will be integrated into the vacuum apparatus to probe the 1S-2S two-photon transition. In the future, it is planned to load the slow hydrogen atoms into a magnetic minimum trap using a cold lithium buffer gas.

[1] S. Schmidt et al. J. Phys.: Conf. Ser. 1138, 012010 (2018)

Q 26: Poster – Ultrashort Pulses and Strong Fields (joint session K/Q)

Time: Tuesday 17:00–19:00 Location: Philo 1. OG

Q 26.1 Tue 17:00 Philo 1. OG

Theoretical prediction of vibrational effects in multi-photon spectroscopy — •herve tajouo tela, deshan li, and julien bloino — Scuola Normale Superiore Pisa, Italy

The numerical investigation of molecular optical properties is essential for advancing our understanding of light*matter interactions. In this work, we present computational approaches for modeling two- dimensional (2D) photon absorption processes, with a particular focus on benchmarking 2D electronic*electronic transitions. These benchmark studies establish a basis for extending the methodology to more general frameworks that incorporate electronic*vibrational coupling. By employing advanced numerical techniques and high-precision algorithms, we aim to achieve accurate simulations of nonlinear optical responses and to predict spectroscopic signatures in complex molecular systems. Ultimately, this work seeks to improve the reliability of numerical simulations in capturing the fundamental features of multiphoton absorption processes, with applications spanning spectroscopy, photophysics, and quantum dynamics.

Q 26.2 Tue 17:00 Philo 1. OG

A Flexible Laser Micromachining Platform for Fabricating Integrated Photonic Systems in Transparent Materials — •Yassin Nasr, Patrick Hildebrand, Veronica Montoya, Thilo Danner, Andreas Michalowski, and Tobias Menold — University of Stuttgart - Institut für Strahlwerkzeuge (IFSW), Stuttgart, Germany

The increasing demand for compact, robust, and fully integrated photonic systems requires fabrication tools that can structure transparent materials with high precision and three-dimensional flexibility. Many established laser micromachining studies rely on highly specialized setups optimized for a single process, limiting systematic comparisons and slowing scientific progress. To overcome these constraints, we developed a laser micromachining platform that combines multiple ultrafast laser processes into one versatile system architecture.

The setup combines a high-NA microscope objective for generating micrometer-scale focal spots, a galvanometric scanner and a high-precision XYZ translation stage for dynamic 3D processing and a spatial light modulator (SLM) for dynamic correction of aberrations and controlled beam shape inside transparent materials.

This architecture enables scientific investigations of various laser-based micromachining processes like direct laser writing of waveguides, selective laser etching to create integrated microstructures like lenses and laser-assisted bonding for joining glass substrates. All these processes form the technological basis for the scalable fabrication of robust integrated photonic systems on one single manufacturing platform.

Q 26.3 Tue 17:00 Philo 1. OG

Spatiotemporal analysis of non-collinear optical parametric oscillators — •Robin Mevert[1,2], Fridolin Jakob Geesmann[1], Oliver Melchert[1,2], Han Rao[1,2], Arun Paudel[1,2], and Uwe Morgner[1,2,3] — [1]Leibniz University Hannover, Institute of Quantum Optics, Hannover, Germany — [2]Cluster of Excellence PhoenixD, Hannover, Germany — [3]Laser Zentrum Hannover e.V., Hannover, Germany

Femtosecond non-collinear optical parametric oscillators exhibit complex spatiotemporal dynamics, making it challenging to predict their steady-state under different input conditions. This study applies a GPU-accelerated 2D+1-dimensional split-step Fourier method to solve a generalized model of the coupled wave equations. It considers all potential second-order nonlinear mixing processes, including phase matching, diffraction, and walk-off, for all interacting pulses. Additionally, the model includes the impact of third-order nonlinear effects, such as self-phase modulation (SPM) and cross-phase modulation (XPM), on the resulting cavity mode. The cavity roundtrip is modelled using the Collins diffraction integral, with additional losses, dispersion, and spatial filtering due to the limited size of the mirrors.

Q 26.4 Tue 17:00 Philo 1. OG

Dressed-state-enhanced harmonic generation at high intensities with a single driving field — •Oskar Ernst and Thomas Halfmann — TU Darmstadt, Institut für angewandte Physik, Darmstadt, Germany

We investigate 5th and 7th harmonic generation of ultrashort picosecond laser pulses in the vacuumultraviolet (VUV) regime, enhanced by laser-induced dressed states in xenon. The pump laser for harmonic generation simultaneously acts as a control field, preparing multiple dressed states with large Autler-Townes splittings in the terahertz range. We observe well-defined dressed states even at large intensities up to 30 TW/cm^2, corresponding to an already small Keldysh parameter around 2. The presence of dressed states compensates the Stark shift, enabling resonantly enhanced frequency conversion by up to one order of magnitude across a broad spectral window of approximately 40 nm, tunable via laser wavelength and intensity. Our results demonstrate that significant resonance enhancements of VUV generation via dressed states are possible and relevant even without an additional control field.

Q 26.5 Tue 17:00 Philo 1. OG

Time-Trapping Towards Manipulation of Single-Photon Wavepackets — •Marvin Franzke[1], Fridolin Geesman[1], David Zuber[1,2], Ihar Babushkin[1,2,3], and Uwe Morgner[1,2] — [1]Leibniz University Hannover, Institute of Quantum Optics, Welfengarten 1, 30167 Hannover, Germany — [2]Cluster of Excellence PhoenixD (Photonics, Optics, and Engineering-Innovation Across Disciplines), 30167 Hannover, Germany — [3]Max Born Institute, Max-Born-Straße 2a, 10117 Berlin, Germany

In this project we are going to demonstrate experimentally a recent, theoretically suggested way of trapping and manipulating femtosecond-long weak pulses. A soliton propagating in a gas-filled hollow-core fiber creates a refractive index potential capable of trapping a much weaker pulse or even single photons. A weak pulse, described by linear optics, would always undergo dispersion, but trapping inside a soliton, described by nonlinear optics, allows for a dispersion-free propagation. Furthermore, trapping allows manipulation of the weak pulse by manipulating the soliton trap, since the weak pulse follows adiabatically. Here, two components of the experimental setup are discussed: an optical parametric amplifier (OPA) delivering the pulses, and diffractive optical elements (DOEs) converting the Gaussian mode from the OPA to higher order modes. These higher order modes are a crucial feature because the soliton and the weak pulse are at different wavelengths. By choosing different higher order modes for them and tuning the gas pressure, group velocity matching can be achieved. Furthermore, theoretical considerations about time-trapping are presented.

Q 26.6 Tue 17:00 Philo 1. OG

Towards All-Optical Attoclock Measurements in Noble Gases Using Short-Wave Infrared Laser Pulses — •Fridolin Geesmann[1], Morten Drees[2], David Zuber[1,3], Ihar Babushkin[1,3,4], and Uwe Morgner[1,3] — [1]Leibniz University Hannover, Institute of Quantum Optics, Hannover, Germany — [2]University of Ottawa, Ottawa, Canada — [3]Cluster of Excellence PhoenixD, Hannover, Germany — [4]Max Born Institute, Berlin, Germany

Laser driven ionization of noble gases gives rise to a plethora of interesting effects, such as the so-called Brunel radiation, which originates from the ionization and subsequent acceleration of electrons in the strong optical electric field. The study of this radiation, in particular of its polarization state, allows for detailed insights into the fundamental principles of light-matter interaction. Here, we report on the usage of elliptically polarized short-wave infrared femtosecond laser pulses generated by a home-built optical parametric amplifier to drive the generation of Brunel harmonics in Argon, which then encode information about the tunnel time of the electrons through the Coulomb barrier of the gas atoms in the rotation of their polarization ellipse. Our setup facilitates ultrashort laser pulses centered around 2 μm that exhibit pulse energies of up to 110 μJ and pulse durations below 40 fs. Furthermore, it allows for the simultaneous measurement of the intensity-dependent polarization state of the third and fifth harmonic from the Brunel field, thus enabling an all-optical characterization of the tunnelling time of the matter under test.

Q 26.7 Tue 17:00 Philo 1. OG

Probing High-Order Susceptibilities of monolayer MoS_2 via High Harmonic Generation: TDDFT approach — •Yeganehsadat Alvankar[1,2], Elnaz Irani[2], Hamid Talkhabi[1,2], and Mohammad Monfared[3] — [1]3ICMM, Centro Superior de Investigaciones Cientficas, Sor Juana Ines de la Cruz, 3 Cantoblanco, 28049 Madrid, Spain — [2]Department of Physics, Faculty of Basic Sciences, Tarbiat Modares University, P.O. Box 14115-175, Tehran, Iran — [3]Institute of Theoretical Physics, Leibniz University Hannover, Appelstraße 2, 30167 Hannover, Germany

High-harmonic generation (HHG) is a powerful method for probing high-order nonlinear optical responses in solids, across both perturbative and non-perturbative regimes.

Here, we use time-dependent density functional theory (TDDFT) to compute the nonlinear susceptibilities ($\chi^{(5)}, \chi^{(7)}, \chi^{(9)}$) of monolayer MoS_2 via HHG. Simulations employ intense ultrafast laser pulses ($\lambda_0 = 600, \mathrm{nm}$) with peak intensities from 0.2-1.2 TW/cm^2.

Our results exhibit power-law scaling $\mathrm{Yield}_N = A_N I^N$ and interband polarization, enabling direct extraction of higher-order susceptibilities. We also observe strong crystal orientation dependence, with anisotropic behavior across harmonic orders, emphasizing the role of polarization control in 2D material characterization.

Unlike previous methods (e.g., attosecond streaking) that inferred lower-order susceptibilities indirectly, HHG directly reveals higher-orders responses without broad spectra or indirect analysis. Quantifying such nonlinearities is key to advancing ultrafast photonic.

Q 26.8 Tue 17:00 Philo 1. OG

Neural network reconstruction of hamiltonians and transition dipole couplings from transient absorption spectra — •Ronald Cardenas, Ulf Saalmann, and Jan-Michael Rost — MPI-PKS, Dresden, Germany

Transient absorption spectroscopy (TAS) provides insight into ultrafast electronic dynamics, yet the resulting spectra are often challenging to interpret with conventional tools. In this work, we develop a Convolutional Neural Network (CNN) that reconstructs effective Hamiltonian matrices directly from TAS data. In addition to recovering effective energy levels, the model also predicts transition dipole couplings, which determine electronic coherences and state interactions under external fields. These couplings are essential to determine the optical response for linear and nonlinear optical processes. As they cannot be measured directly, they are typically obtained from ab initio calculations. Such calculations can become demanding for larger systems or situations involving many excited states. The CNN approach provides an alternative route to estimating these couplings using only spectroscopic input. The reconstructed Hamilton matrices enable the calculation of dynamical properties such as time-dependent dipole moment and polarization response. They can also be used for simulations of open-system Lindblad dynamics, coherent control schemes, nonlinear spectroscopy, and strong-field ionization models. Overall, our approach links experimental TAS data to the theoretical parameters needed to model ultrafast light*matter interactions, offering a flexible framework for complex molecular systems.

Q 26.9 Tue 17:00 Philo 1. OG

Neural network reconstruction of hamiltonians and transition dipole couplings from transient absorption spectra — •Ronald Cardenas, Ulf Saalmann, and Jan-Michael Rost — MPI-PKS, Dresden, Germany

Transient absorption spectroscopy (TAS) provides insight into ultrafast electronic dynamics, yet the resulting spectra are often challenging to interpret with conventional tools. In this work, we develop a Convolutional Neural Network (CNN) that reconstructs effective Hamiltonian matrices directly from TAS data. In addition to recovering effective energy levels, the model also predicts transition dipole couplings, which determine electronic coherences and state interactions under external fields. These couplings are essential to determine the optical response for linear and nonlinear optical processes. As they cannot be measured directly, they are typically obtained from ab initio calculations. Such calculations can become demanding for larger systems or situations involving many excited states. The CNN approach provides an alternative route to estimating these couplings using only spectroscopic input. The reconstructed Hamilton matrices enable the calculation of dynamical properties such as time-dependent dipole moment and polarization response. They can also be used for simulations of open-system Lindblad dynamics, coherent control schemes, nonlinear spectroscopy, and strong-field ionization models. Overall, our approach links experimental TAS data to the theoretical parameters needed to model ultrafast light-matter interactions, offering a flexible framework for complex molecular systems.

Q 26.10 Tue 17:00 Philo 1. OG

Open-shell electron dynamics with restricted open-shell configuration interaction singles — •ka hei lee[1,2], pascal krause[1], and annika bande[1,2] — [1]Inorganic Chemistry Institute, Leibniz University Hannover, Germany — [2]Theory of Electron Dynamics and Spectroscopy, Helmholtz-Zentrum Berlin, Germany

The description of correlated, ultrafast electron dynamics in polyatomic many-electron molecules is a challenging task. The time-dependent configuration interaction (TDCI) method has shown to correctly describe the light-induced excitation processes on the natural time scale of the electrons. By employing atom-centered basissets formed spin orbitals, monitoring the evolution of the electronic wave packet in TDCI framework becomes possible and analysis tools of the electron-hole-pair formation are available. [1, 2]

The study of dynamics of open-shell systems states an even bigger challenge as it requires a multi-configurational character for the spin-adapted wavefunction. In this poster, I present how the time-dependent restricted open-shell configuration interaction singles (TD-ROCIS) methods can be employed to monitor light-driven electron dynamics calculations for open-shell systems.

[1] F. Langkabel, P. A. Albrecht, A. Bande, P. Krause, Chem. Phys., 557, 111502 (2022)

[2] F. Langkabel, P. Krause, A. Bande, WIREs Comput Mol Sci., 14, e1696 (2024)

Q 26.11 Tue 17:00 Philo 1. OG

Impact of vertical Lidar misalignment on turbulence characterization for wind energy applications — •Vidana Popkova[1], Florian Jäger[1,2], Lukas Pauscher[1,2,3], Fabian Spallek[1], and Stefan Yoshi Buhmann[1] — [1]University of Kassel, Germany — [2]Fraunhofer IEE, Kassel, Germany — [3]Vrije Universiteit Brussel, Belgium

To evaluate the quality of possible wind-park locations, accurate knowledge of the turbulence characteristics of the expected wind-velocity-field is essential. The turbulence properties are commonly described by the variance of the field and may be extracted from measurements or simulations. Multi-LiDAR (Light Detection And Ranging) setups offer precise measurements for determining turbulence properties, but some systematic measurement uncertainties remain hard to control for. In particular, vertical offsets between LiDAR beams can drastically bias derived variances due to the large impact of the beam configuration on the measured data. We use a modified Mann model [1] to calculate the turbulence properties based on the spectral tensor and simulate dual-LiDAR configurations to study the influence of vertical offsets on the resulting variances. To this end, we introduce offsets directly in the spectral domain and examine their impact for varying atmospheric parameters. Several significant beam configurations are analyzed and compared with data from long-term mast measurements. The resulting theoretical framework can subsequently be used to develop turbulence-correction methods for misaligned LiDAR setups.

[1] Mann, J., J. Fluid Mech., 273, 141-168 (1994).

Q 26.12 Tue 17:00 Philo 1. OG

Methods and hurdles for a live shot to shot polarization diagnostic — •Moritz Mogilowski[1,2] and Markus Illchen[1,2] — [1]Universität Hamburg, Hamburg, Germany — [2]CFEL, Hamburg, Germany

With the recent advances of free electron lasers, pushing further into the attosecond time regime with ultra short pulses investigation of the chirality and and its time dependence on electronic movements is becoming feasible. The polarization of the FEL pulse is critical and its charactisation is not only important for analysing the data but also an important live metric for the machine operators. In this poster a robust and flexible approach to a shot based live polarization diagnostic based on almost intrusion free electron time of flight spectroscopy is shown. Common failures and their remedies are also discussed.

Q 26.13 Tue 17:00 Philo 1. OG

A Lab-based High Brilliance Secondary Source for Hard X-ray Generation — •Lion Günster, Luka Petersen, Jose Mapa, Greta Paruschke, Philip Mosel, Sven Fröhlich, Andrea Trabattoni, Uwe Morgner, and Milutin Kovacev — Leibniz Universität Hannover - Institut für Quantenoptik, Hannoverm Deutschland

The development of high-brilliance X-ray sources is one of the key factors driving rapid progress in industrial and medical applications. Due to the limitations of conventional X-ray sources, this growing demand has stimulated research into laser-based secondary sources. Combined with very high-power-laser, very promising results have already been reported. Within the framework of the XProLas project we construct and test such a laser-produced plasma X-ray source for their usability in industrial applications.

Femtosecond pulses with a pulse energy of 10 mJ are focused on a copper wire target reaching laser intensities of $2 * 10^{18}$ W/cm^2. To enable continuous operation of the source multiple debris mitigation schemes have been implemented. With a repetition rate of 50 kHz we aim to achieve brilliance levels of over $5 * 10^{13}$ photons/s sr in Cu K_α, surpassing state-of-the-art conventional X-ray sources by one order of magnitude.

Q 26.14 Tue 17:00 Philo 1. OG

New light in the lab for single-particle imaging experiments — •Jasper Boultwood[1], Indrani Dey[1], Frederic Ussling[1], José Gómez Torres[1], Yves Acremann[2], Alessandro Colombo[1], Linos Hecht[1], Isabelle Bollier[1], Ehsan Hassanpour Yesagi[1], Jannis Lehmann[2], Katharina Kolatzki[1], Mirjam Kunz[1], Mario Sauppe[1], Angela Vidoni[1], Simon Wächter[1], Björn Senfftleben[1], and Daniela Rupp[1] — [1]Nanostructures and Ultrafast Science, ETH Zürich — [2]D-PHYS, ETH Zürich

Lab-based coherent diffraction imaging (CDI) of free-flying isolated nanoparticles has only recently become feasible and opens up new research opportunities. Short-wavelength pulses focused to high intensities are required, which are connected to rather extreme conditions for the high-harmonic generation (HHG) process. We investigate the use of different focusing geometries and driving wavelengths to optimize XUV pulse generation from a high-power NIR laser amplifyer (800 nm, 20 mJ, 30 fs). Interestingly, XUV generation in a Xenon gas cell using a 400 nm driving wavelength from second harmonic generation (SHG) in a BBO crystal results in the production of a single harmonic instead of four harmonics typical for an 800 nm driver. This single-line output is of interest for CDI applications as monochromatic diffraction creates clearer interference structures.

Q 26.15 Tue 17:00 Philo 1. OG

X-ray and Electron Emission from peeling Adhesive Tape — Jose L. Mapa[1], •Luka Petersen[1], David Theidel[3], Philip Mosel[1], Charlotte Fischer[1,2], Sven Froehlich[1], Kim-Alessandro Weber[1], Peter Oberta[4,5], Jan-Willem Vahlbruch[2], Hamed Merdji[3], Uwe Morgner[1], and Milutin Kovacev[1] — [1]Leibniz University Hannover, Institute of Quantum Optics, Welfengarten 1, 30167 Hannover, Germany — [2]Leibniz University Hannover, Institute of Radioecology and Radiation Protection, Herrenhäuser Str. 2, 30419 Hannover, Germany — [3]Laboratoire dOptique Appliquée, École nationale supérieure de techniques avancées (ENSTA) ParisTech, CNRS, École polytechnique, 828 Boulevard des Maréchaux, 91120 Palaiseau, France — [4]Rigaku Innovative Technologies Europe s.r.o., Dolní Brežany, 252 41, Czech Republic — [5]Institute of Physics of the Czech Academy of Sciences, Na Slovance 1999/2, Praha 8, 182 00, Czech Republic

In recent years, several scientific groups have investigated X-ray generation by peeling adhesive tape in vacuum. X-ray generation results from electron emission during the peeling and their interactions with surrounding materials. These studies mainly focused on the tape, system properties, and electron interactions near the detachment point. We examine electron interactions with solid materials along their travel path. We observe a non-homogeneous spatial distribution of electron energies, which we compare with numerical simulations. It shows peeling adhesive tape can serve as a simple, low-cost X-ray source for educational demonstrations and small lab experiments.

Q 26.16 Tue 17:00 Philo 1. OG

Dispersive-Wave Generation in a Kagome-Type Hollow-Core Fibre by Few-Cycle-Pulses — •David Zuber[1,2], Fridolin Jakob Geesmann[1], Ihar Babushkin[1,2,3], and Uwe Morgner[1,2] — [1]Leibniz University Hannover, Institute of Quantum Optics, Hannover, Germany — [2]Cluster of Excellence PhoenixD, Hannover, Germany — [3]Max Born Institute, Berlin, Germany

Tunable ultrashort pulses in the ultraviolet (UV) spectral range have attracted significant attention in a variety of applications, including pump-probe spectroscopy, lithography, and the control of chemical reactions. Conventional laser systems are often limited by the availability of suitable gain media, while their nonlinear counterparts such as optical parametric amplifiers or oscillators face constraints imposed by crystal absorption, phase-matching conditions, and the availability of sufficiently energetic pump photons. The presented UV source is based on dispersive-wave generation in a gas-filled Kagome-type hollow-core fibre. The fibre is pumped with a few-cycle OPCPA system, thereby generating a tunable UV radiation peak accompanied by a broadband background spanning more than 1 PHz. The experimental findings are supported by numerical simulations, which demonstrate the potential for producing few-cycle pulses directly in the UV. In addition, the paper discusses prospects for extending this concept toward the extreme-ultraviolet regime.

Q 26.17 Tue 17:00 Philo 1. OG

Temperature-dependence of two-color laser-induced currents in graphene — •Celina Hüttner[1], Weizhe Li[1], Daniel Lesko[1,2], and Peter Hommelhoff[1,2] — [1]Department Physik, Friedrich-Alexander-Universität (FAU) — [2]Department Physik, Ludwig-Maximilians-Universität München (LMU)

Strong laser fields have previously been used to induce directional currents in solids via symmetry breaking, enabling electronic coherent control on the femtosecond timescale. In graphene, an inversion symmetric semi-metal with extraordinary electronic and optical properties, the photocurrent generation can be controlled by shaping the laser field, for instance through control of the carrier envelope phase or by combining harmonics of a laser pulse. As the latter requires a coherent interaction of both pulses and the electrons in graphene, it enables detailed exploration of decoherence- and dephasing-mechanisms. While the two-color photocurrents have been extensively studied before, the role of phonon-electron scattering remains unclear. In order to investigate this process, we cool graphene to temperatures below 25 K via a continuous flow cryostat setup and measure the two-color photocurrent, at both room and cryogenic temperature. We study the behavior of the photocurrent at different temperatures by varying field strength, polarization and the two-color-phase.

Q 26.18 Tue 17:00 Philo 1. OG

Investigation of the Thermal Behaviour of Yb:YAG and Yb:LuAG in High-Power Bulk Amplifiers — •Julian Siller[1], Arun Paudel[1], Han Rao[1,2], David Zuber[1,2], and Uwe Morgner[1,2] — [1]Leibniz University Hannover, Institute of Quantum Optics, Hannover, Germany — [2]Cluster of Excellence PhoenixD, Hannover, Germany

Ytterbium-doped gain materials are widely used in modern high-power ultrafast laser systems, where thermally induced effects strongly influence beam quality, wavefront stability and hence achievable focusability. While Yb:YAG is a well-established workhorse for solid-state amplifiers, recent studies suggest that Yb:LuAG may exhibit significantly reduced thermo-optical distortions, potentially offering advantages for high power operation. Here, we report on the development of a home-built bulk laser amplifier designed to directly compare the thermal behavior of Yb:YAG and Yb:LuAG under identical pumping conditions. The setup enables controlled high-power pumping in the near-infrared regime and allows for simultaneous measurements of thermal lensing and temperature-dependent gain dynamics. Using beam profiling and M square analysis, we quantify the evolution of thermally induced distortions within each crystal and assess their impact on the amplified output. We expect that the observed differences in the thermo-optical response of the two materials will provide insights into the suitability of Yb:LuAG as a low-distortion alternative to Yb:YAG for next-generation high-power bulk amplifiers.

Q 26.19 Tue 17:00 Philo 1. OG

Characterization of the Temporal Pulse Contrast for Laser-Produced Plasma Applications — •Pia Koopmann, Peer Biesterfeld, Sven Fröhlich, and Milutin Kovacev — Leibniz Universität Hannover - Institut für Quantenoptik, Welfengarten 1, 30167 Hannover, Germany

Ultrafast, high-intensity laser systems are increasingly used to generate secondary radiation sources, such as X-rays and particle beams, offering promising capabilities for scientific and industrial applications. At these intensities, even the comparatively low-intensity laser pedestals and pre-/post-pulses can exceed material ionization thresholds. In particular, the formation of pre-plasma significantly changes the interaction conditions. This can result in effects such as an increased emission of hazardous radiation. Therefore, understanding and controlling these effects is critical for optimizing secondary source performance.

We present the development of an in-house built third-order autocorrelator, designed to characterize the temporal contrast of ultrafast laser systems with high dynamic range. A third-order autocorrelator provides the sensitivity necessary to capture these features and enables systematic studies of how the temporal contrast influences plasma dynamics and the efficiency of Laser-produced plasma sources. The device is optimized to provide the high dynamic range required to resolve weak ns to ps temporal structures, such as pedestals and pre-/post-pulses, which play a decisive role in laser-matter interaction dynamics.

Q 27: Poster – Precision Spectroscopy of Atoms and Ions (joint session A/Q)

Time: Tuesday 17:00–19:00 Location: Philo 1. OG

Q 27.1 Tue 17:00 Philo 1. OG

Towards High Precision Laser Spectroscopy on a Cold Beam of Atomic Lithium — •Hannah Jost, Tim Redelbach, Gregor Schwendler, and Randolf Pohl — Institut für Physik/ QUANTUM, Johannes Gutenberg-Universität Mainz, Staudingerweg 7, 55128 Mainz, Germany

Precision measurements of simple atoms and molecules are useful because comparison with equally precise theory calculations can test the theory and determine fundamental physical constants [1]. We are aiming at new precision measurements of the lithium D lines, for the first time using a cold atomic beam obtained from a 2D-MOT [2], and using an actively stabilised retroreflector [3, 4] to eliminate the first order Doppler shift. Comparison with ongoing experiments on muonic lithium [5] will in addition enable stringent tests of a variety of system-

atics relevant for recent and ongoing experiments in atomic hydrogen and deuterium [6], such as Quantum Interference [7], or the light-force shift [6].

[1] P. Mohr et al., arXiv 2409.03787 (2024). [2] T. Tiecke et al., Phys. Rev. A 80 1094-1622 (2009). [3] V. Wirthl et al., Optics Express 29, 7024 (2021). [4] V. Wirthl et al., Optics Express 30, 7340 (2022). [5] B. Ohayon et al., Physics 6, 206-215 (2024). [6] A. Beyer et al., Science 358, 6359 (2017). [7] T. Udem et al., Annalen der Physik 531, 1900044 (2019).

Q 27.2 Tue 17:00 Philo 1. OG

Metallic-Magnetic Calorimeters for Efficient High Resolution X-ray Spectroscopy for Energies up to 150 keV — •Daniel Kreuzberger, Andreas Abeln, Hendrik Hadenfeldt, Daniel Hengstler, Andreas Reifenberger, Daniel Unger, Andreas Fleischmann, Loredana Gastaldo, and Christian Enss — Kirchhoff-Institute for Physics, Heidelberg University, Germany

Metallic Magnetic Calorimeters are cryogenic detectors for broadband x-ray spectroscopy with high energy resolution and small, well understood non-linearity. They consist of a metallic particle absorber, typically made of gold and a paramagnetic temperature sensor made of an erbium doped noble metal host material. If a photon is absorbed, its energy is converted to heat, leading to a temperature change of the sensor material. This temperature rise changes the magnetization of the sensor material, which is read out by a sensitive SQUID magnetometer.

Experiments on highly charged ions and light muonic atoms have brought up the necessity to build densely packed arrays of MMCs with a high stopping power for photon energies up to 150 keV. This can be achieved with the presented new microfabrication-process for 120 μm thick absorbers made of electroplated gold. We also present fabrication results for the fast thermalization of the MMCs using the backside of the silicon substrate, which can be achieved by using DRIE processes, and filling these TSVs with copper. Finally we present characterization results for two different MMC arrays fabricated with those newly developed processes and results from most-recent beamtimes.

Q 27.3 Tue 17:00 Philo 1. OG

Spectroscopy and laser-cooling of zinc — •Lukas Möller, Felix Waldherr, David Röser, and Simon Stellmer — Universität Bonn, Germany

Laser-cooling and trapping of neutral atoms is a widely used technique in contemporary atomic physics and has been demonstrated for many elements of the periodic table. The element zinc, an alkaline-earth-like metal, is a promising candidate for a new optical clock. We report on the development of a DUV cw-laser source at 213.9 nm, magneto-optical trapping of zinc and our work towards narrow-line cooling and isotope shift spectroscopy on the narrow cooling transition of zinc.

Q 27.4 Tue 17:00 Philo 1. OG

Towards large-area 256-pixel MMC arrays for high resolution X-ray spectroscopy — •Andreas Abeln, Hendrik Hadenfeldt, Daniel Hengstler, Lucas Herbstritt, Daniel Kreuzberger, Andreas Reifenberger, Andreas Fleischmann, Loredana Gastaldo, and Christian Enss — Kirchhoff Institute for Physics, Heidelberg University

Metallic Magnetic Calorimeters (MMCs) are energy-dispersive cryogenic particle detectors. Operated at temperatures below 50 mK, they provide very good energy resolution, high quantum efficiency as well as high linearity over a large energy range. In many precision experiments in X-ray spectroscopy the photon flux is small, thus a large active detection area is desirable. Therefore, we develop arrays with increasing number of pixels.

In this contribution we present a detector setup featuring a novel dense-packed 16×16 pixel MMC array. The pixels provide a total active area of 4 mm × 4 mm and are equipped with 5 μm thick absorbers made of gold. This ensures a stopping power of at least 50 % for photon energies up to 20 keV. The expected energy resolution is 1.4 eV (FWHM) at an operating temperature of 20 mK. For the cost-effective read-out of the 128 detector channels we envisage the flux-ramp multiplexing technique. We present first results of the detector characterization obtained utilizing parallel 2-stage dc-SQUID read-out chains. We discuss the detector performance, focusing on the thermal behavior within the detector as well as to the thermal bath.

Q 27.5 Tue 17:00 Philo 1. OG

Microfabricated Penning trap for quantum logic inspired CPT-tests — •Philipp Hoffmann[1], Julia Coenders[1], Nikita Poljakov[1], Jan Schaper[1], Marek Prasse[1], Juan Cornejo[2], Jacob Stupp[1], Stefan Ulmer[4,5], and Christian Ospelkaus[1,3] — [1]Leibniz Universität Hannover, Germany — [2]Universidad de Cádiz, Spain — [3]Physikalisch-Technische Bundesanstalt, Braunschweig, Germany — [4]Ulmer Fundamental Symmetries Laboratory, RIKEN, Japan — [5]Heinrich-Heine-Universität Düsseldorf, Germany

Within the framework of the BASE collaboration, we focused on testing CPT symmetry by performing high-precision measurements of the g-factor of protons [1] and antiprotons [2]. We aim to employ quantum logic spectroscopy [3] using a laser-cooled $^{9}Be^{+}$ ion to improve the sampling rate and statistical uncertainty of these measurements. Sympathetic ground-state cooling will happen through coupling. Our objective is to couple [4] the mbox(anti-)proton to the $^{9}Be^{+}$ ion, which will happen in a double-well potential. Shaping this potential is challenging, because of the different particles. Coupling is also essential for spin-state detection of the (anti-)proton. This coupling should occur within a microfabricated section of our Penning trap stack, as presented in this contribution, alongside an outline of the process for fabricating these electrodes via selective laser-induced etching (SLE) on fused silica wafers. [1] G. Schneider et. al. Science 358 (2017) [2] C. Smorra et al., Nature 550 (2017) [3] D.J.Schneider et al., Phys. Rev. A 42 (1990) [4] K. R. Brown et. al., Nature 471 (2011).

Q 27.6 Tue 17:00 Philo 1. OG

Digital Pulse Shape Analysis for Metallic Magnetic Calorimeters (MMC) — •J. H. Walch[1,2,3], D. A. Schnauss-Müller[1,2,3], M. O. Herdrich[1,2,3], Ph. Pfäfflein[1,2,3], G. Weber[1,2,3], D. Hengstler[4], A. Fleischmann[4], Ch. Enss[4], and Th. Stöhler[1,2,3] — [1]HI-Jena — [2]IOQ, FSU — [3]GSI — [4]KIP

In the recent years, MMCs have emerged as excellent single photon detectors, exhibiting a broad spectral acceptance range from a few to hundreds of keV and a high energy resolution of $E/\Delta E(FWHM) \approx 6000$ [J. Geist. PhD thesis, 2020]. Together with their fast rise time, they provide a superb opportunity for fundamental research in atomic physics. The MMC detector absorbs an incident photon. The subsequent heat up of an absorber-sensor pair leads to a change in magnetisation of the sensor generating a signal dependent on the photons energy. The shape depending on the intrinsic detector response, additional noise and artefacts from various sources. To achieve the full detector performance and accurately measure incident photon energies, it is necessary to extract the relevant pulse features while suppressing noise contributions. Several techniques to maximise statistical information involving finite impulse response filters have been explored. Additional correction techniques are needed to mitigate the effects of integral nonlinearities and temperature drift of ADCs gain behaviour. This work presents an overview of the involved steps and compare several digital filters with regard to their resolving power. In particular: a Moving Window Deconvolution based algorithm presented by M. O. Herdrich and the Optimal filter as described e.g. by A. Fleischmann.

Q 27.7 Tue 17:00 Philo 1. OG

Development of a cryogenic Paul trap setup for high-precision quantum-logic spectroscopy — •Stepan Kokh, Magdalena Winkelvoss, Anton Sterr, Sophia Dorra, Melina Gizewski, Finja Mayer, Maili Schube, José R. Crespo López-Urrutia, Thomas Pfeifer, and Vera M. Schäfer — Max-Planck-Institut für Kernphysik, Heidelberg

Several theories for physics beyond the standard model predict a variation of the fine-structure constant α. The current upper limit on its variation is set by high-precision spectroscopy in singly charged ytterbium. Cf^{15+} and Cf^{17+} offer higher sensitivity to α and low sensitivity to external perturbations, thereby opening the potential to improve on these bounds. To achieve the required precision, care must be taken in the design of the experiment to minimise systematic errors. Here, we present a Paul trap setup designed to fulfill these requirements. Two Paul trap setups are placed on the same optical table, to perform frequency comparison between the two charge states. For improved vacuum, to suppress charge exchange with the HCIs, the Paul trap environment needs to be cooled to 4K. This is achieved through a closed-cycle cryocooler with a helium gas-exchange interface that should reduce the vibrations at the trap to below 10 nm. A superconducting niobium shield is installed around the 4K stage to suppress magnetic field noise and increase the coherence time. The system is designed for fast and easy assembly and cool-down to simplify debugging issues inside the vacuum chamber.

Q 27.8 Tue 17:00 Philo 1. OG

Calcium optical clock as an absolute frequency standard for the thorium nuclear transition — •Darius Fenner[1], Valerii Andriushkov[1,2], Keerthan Subramanian[1], Ke Zhang[1], Srinivasa Pradeep Arasada[1], Florian Zacherl[1], Yumiao Wang[1,4], Christoph E. Düllmann[1,2], Dmitry Budker[1,2,3], Ferdinand Schmidt-Kaler[1], and Lars von der Wense[1] — [1]Johannes Gutenberg-Universität Mainz — [2]Helmholtz Institut Mainz — [3]University of California, Berkeley, USA — [4]Fudan University, Shanghai, China

Nuclear clocks are expected to improve the accuracy of optical clocks due to their reduced susceptibility to external fields and higher transition frequencies. They are based on the transition of the low-lying and long-lived isomeric state of thorium-229. In our setup, thorium and calcium ions are co-trapped in a linear Paul trap for sympathetic cooling. In the future, to excite the thorium nucleus with a cw laser, the frequency of the nuclear transition must be compared to a known frequency standard. This poster presents the construction of an optical clock based on a trapped Ca^+ ion, using the 729 nm clock transition between $S_{1/2}$ and $D_{5/2}$. The clock laser is first stabilized using the Pound-Drewer-Hall technique to reach a linewidth at the Hertz level. After locking the laser to the calcium ion, its frequency will be measured using an optical frequency comb. The goal is to reach an accuracy of 10^{-15}. This project is supported by the BMFTR Quantum Futur II Grant Project NuQuant (FKZ 13N16295A) and DFG Project TACTICa (grant agreement no. 495729045).

Q 27.9 Tue 17:00 Philo 1. OG

MMC based high-precision spectroscopy on muonic atoms — •Tim Redelbach for the QUARTET-Collaboration — Institute of Physics, Mainz, Germany

The QUARTET collaboration aims for high-precision spectroscopy of muonic atoms at the Paul Scherrer Institute (PSI) to extract nuclear charge radii in simple atomic systems. A key motivation of the experiment is to reduce the relative uncertainties of nuclear charge radii for stable isotopes ranging from Lithium to Neon. The current uncertainties in this region suffer mainly from experimental uncertainties. To fill this uncertainty gap, Metallic Magnetic Calorimeters (MMC) are employed, which provide a unique combination of superb energy resolution, linearity and stability. This contribution will present the experimental concept and first results from the beam time conducted in October 2025, highlighting the performance of the MMC-based detection system and the current status of data analysis on the stable Oxygen isotopes O16, O17 and O18.

Q 27.10 Tue 17:00 Philo 1. OG

Preparation of actinide samples for applications in fundamental physics and chemical studies — •A. T. Loria Basto[1,2], C. Mokry[1,2], J. Runke[1,3], Ch .E. Düllmann[1,2,3], and D. Renisch[1,2] — [1]JGU, Mainz, Germany — [2]HIM, Mainz, Germany — [3]GSI, Darmstadt, Germany

Samples of radioisotopes serve as sources and targets in many basic chemistry and physics related research projects. Our group specializes in the production of tailor-made samples, for which a variety of parameters have to be considered. The main ones include isotopic purity, layer thickness and homogeneity as well as geometry. We present the methods available at JGU and within our collaboration network to produce, separate and characterize radionuclide samples, mainly of actinide isotopes. We also highlight the production and characterization of experiment-specific samples and give an overview of applications in Mainz as well as in national and international collaborations.

Q 27.11 Tue 17:00 Philo 1. OG

Heating rate measurements by time-resolved detection of single-phonon excitations — •Sylvain Noël[1,2], Till Rehmert[1,2], Gabriele Gatta[1,3,4], Maximilian J. Zawierucha[1,2], Piet O. Schmidt[1,2], and Fabian Wolf[1] — [1]Physikalisch-Technische Bundesanstalt, Bundesallee 100, 38116 Braunschweig, Germany — [2]Institut für Quantenoptik, Leibniz Universität Hannover, Welfengarten 1, 30167 Hannover — [3]European Laboratory for Nonlinear Spectroscopy (LENS), Via Nello Carrara 1, 50019 Sesto Fiorentino — [4]University of Florence, Department of Physics and Astronomy, Via Sansone 1, 50019 Sesto Fiorentino, Italy

Trapped ions are a well-established platform in quantum science, with applications ranging from quantum computing to high-precision spectroscopy for metrology and as a probe for new physics. These applications rely on long coherence times for coherent manipulation, making it essential to understand and quantify decoherence processes in order to mitigate them. In particular, heating of the trapped ions is one limiting effect for coherence times. Here, we present a new measurement scheme to quantify the motional heating in a Paul trap. The method relies on the time-resolved detection of single-phonon excitations, which allows us to extract the heating rate in the trap. We demonstrate that the method is consistent with the well-known technique based on comparing the red and blue sideband excitations. In addition, the presented method offers a new perspective for the investigation of different heating mechanisms by distinguishing coherent and incoherent motional excitation of the ion.

Q 27.12 Tue 17:00 Philo 1. OG

A pedestrian approach to the computation of atomic structures and processes — •Stephan Fritzsche — Helmholtz-Institut Jena, Germany — Friedrich-Schiller University Jena, Germany

Electronic structure calculations of atoms and ions have a long tradition in physics with applications from basic research to precision spectroscopy, and up to astro and plasma physics. With the Jena Atomic Calculator (JAC), I here present a modern (relativistic) atomic structure code for the computation of atomic amplitudes, properties as well as a large number of excitation and decay processes. JAC [1,2] is based on Julia and provides an easy-to-use but powerful platform to extent atomic theory towards new applications. The toolbox is suitable for (most) open-shell atoms and ions across the periodic table of elements.

[1] S. Fritzsche. A fresh computational approach to atomic structures, processes and cascades. Comp. Phys. Commun., 240, 1 (2019), DOI:10.1016/j.cpc.2019.01.012.

[2] S. Fritzsche. JAC: User Guide, Compendium & Theoretical Background. https://github.com/OpenJAC/JAC.jl, unpublished (02.11.2025).

Q 27.13 Tue 17:00 Philo 1. OG

Frequency Stabilization of a 1762 nm Diode Laser for Quantum Logic Spectroscopy of Barium Ions — •Han Bap, Alexander Windt, Wei Wu, and Tobias Schaetz — Physikalisches Institut, Albert-Ludwigs-Universität Freiburg, Hermann-Herder Straße 3, 79104 Freiburg, Germany

We report on the implementation of a frequency stabilization system for a 1762 nm diode laser, a key component for advanced experiments with trapped Barium ions 138Ba+. This laser wavelength is critical for exciting the ions from the 6S1/2 ground state to the long-lived metastable 5D5/2 state, a necessity for resolve sideband cooling and phonon number measurement. To achieve the required long-term spectral stability and narrow linewidth, we have locked the laser to a high-finesse, ultra-low expansion (ULE) glass cavity using the Pound-Drever-Hall (PDH) technique. We will show the detailed the laser system design, the characterization of the ULE reference cavity, and the implementation of the PDH locking electronics. We present a performance analysis demonstrating a locked linewidth of < 1 kHz and long-term frequency drift of < 0.1 MHz/hour. This stable 1762 nm source is a cornerstone for our ongoing work on quantum logic spectroscopy of the Barium ion's narrow optical quadrupole transition, paving the way for improved study of atom-ion collision between Barium and Rubidium.

Q 27.14 Tue 17:00 Philo 1. OG

How to overengineer an alkali vapor cell characterization system? — •Ingo Hilschenz[1,2], Marvin Kessler[2,3], Folke Dencker[3], Jens Voigt[2], Peter Krüger[2], and Ilja Gerhardt[1] — [1]light & matter group, Institute for Solid State Physics, Leibniz University Hannover, Appelstrasse 2, D-30167 Hannover, Germany — [2]Physikalisch-Technische Bundesanstalt, Abbestraße 2-12, D-10587 Berlin, Germany — [3]Institute of Micro Production Technology, Leibniz University Hannover, An der Universität 2, D-30823 Garbsen, Germany

Hot alkali vapor cells are very versatile in quantum sensing. Their applications cover laser locking, wavelength filters, time standards, and magnetic sensors. Therefore, micro-fabricated cells which deliver highly reproducible specifications are very sought after. As each application has its own requirements, a means of quality control is essential. For example, high vapor pressures might be ideal for a SERF magnetometer, but are less desirable for Doppler-free laser locking. We discuss the quality measures for atomic vapor cells for their specific use. A mostly automated system that combines absorption spectroscopy (Doppler and Doppler-free), longitudinal, and transversal relaxation time measurements are presented. The figures to checks the cell's suitability for magnetometers are discussed in detail. Our system can automatically record spectra around the D_1 and D_2 lines of rubidium, scan the most relevant parameters, and adapts easily to varying cell shapes.

Q 27.15 Tue 17:00 Philo 1. OG

Precision spectroscopy of highly charged ions — •Amir Khan[1], Malte Wehrheim[1], Shuying Chen[1], Lukas J. Spiess[1], Alexander Wilzewski[1], José R. C. López-Urrutia[2], and Piet O. Schmidt[1,3] — [1]Physikalisch Technische Bundesanstalt, Bundesallee 100, 38116 Braunschweig, Germany — [2]Max-Planck Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg, Germany — [3]Institut für Quantenoptik, Leibniz Universität Hannover, Appelstraße 2, 30167 Hannover, Germany

The large binding energy of the remaining electrons in highly charged ions (HCI) makes highly charged ions ideal candidates for applications in frequency metrology and the probing of fundamental physics [1]. So far, we have realized Ar^{13+} and Ca^{14+} optical clocks with an uncertainty of 10^{-16} limited by statistics [2, 3]. In this work we demonstrate how we can overcome this limitation by using a new spectroscopy species Ni^{12+}. We report the identification of the clock [4] and logic transitions and the progress towards a clock with expected systematic and statistical uncertainties at the low 10^{-18} level. Finally, we introduce Os^{16+} as a promising contender for an optical clock. Os^{16+} features more than three clock transitions, with expected small systematic uncertainties and featuring narrow linewidths. References: [1] M. G. Kozlov, M.S. Safronova, et al., Rev. Mod. Phys. 90 (2018) [2] S. A. King, L. J. Spiess, et al., Nature 611, 43 (2022) [3] A. Wilzewski, et al., Phys. Rev. Lett. 134, 233002 (2025) [4] C. Cheung, et al., Phys. Rev. Lett. 135, 093002 (2025)

Q 27.16 Tue 17:00 Philo 1. OG

Towards a Quantum Logic Clock for Precision Spectroscopy of Highly Charged Heavy Ions — •Nadine Homburg[1,2,3], Lukas Kau[1,2,3], Hiroshi Hayakawa[1,2,3], Zoran Andelkovic[2], Thomas Stöhlker[1,2,3,4], and Peter Micke[1,2,3,4] — [1]Helmholtz Institute Jena — [2]GSI Helmholtz Centre for Heavy Ion Research, Darmstadt — [3]Friedrich Schiller University Jena — [4]Abbe Center of Photonics, Jena

Quantum logic spectroscopy (QLS) has driven significant advances in optical frequency metrology by enabling optical clocks based on ions that lack direct laser cooling and state detection transitions. Heavy highly charged ions (HCIs) offer optical transitions with strongly suppressed systematic shifts and enhanced sensitivity to fundamental physics. Substantial progress on medium-mass HCIs has been demonstrated, but extending QLS to the heaviest HCIs remains an open challenge. In this contribution, we present our experimental setup for QLS on heavy HCIs, specifically targeting the optical hyperfine-structure transition in $^{207}Pb^{81+}$ at 1019.7 nm. The experiment, located at GSI in Darmstadt, will provide suitable cryogenic trapping conditions for such extreme charge states. A monolithic linear Paul trap is under development for reduced excess micromotion and trap-related systematic effects. Additionally, the setup includes laser systems for in-situ production of the logic ion Be^{+}, laser cooling to the motional ground state, and coherent manipulation of qubit and HCI clock transitions.

Q 27.17 Tue 17:00 Philo 1. OG

Development of a cryogenic XUV-comb spectroscopy setup for the ^{229}Th nuclear isomer — •anant agarwal[1], lennart guth[1], tobias heldt[1], florian zacherl[2], thorsten schumm[3], lars von der wense[2], thomas pfeifer[1], and josé r. crespo lópez-urrutia[1] — [1]Max-Planck-Institut für Kernphysik, Heidelberg, Germany — [2]Johannes Gutenberg University Mainz, Germany — [3]Vienna University of Technology, Austria

The laser-accessible (148 nm) nuclear transition in ^{229}Th offers intriguing pathways for fundamental physics research and development of novel frequency standards. We aim to investigate the temperature dependence of the transition frequency and variations in the decay time at cryogenic temperatures. In this work, we describe a setup designed to excite the nuclei of Th^{4+} ions embedded in a $Th:CaF_2$ crystal cooled in a helium cryogenic environment, using an extreme-ultraviolet (XUV) frequency comb. The XUV comb is generated as the 7^{th} harmonic of a near-infrared frequency comb through intra-cavity high harmonic generation.

Q 27.18 Tue 17:00 Philo 1. OG

Development of a YBCO-based step-up resonator for cryogenic Paul traps — •Hiroshi Hayakawa[1,2,3], Nadine Homburg[1,2,3], Elena Jordan[5], Lukas Kau[1,2,3], and Peter Micke[1,2,3,4] — [1]Helmholtz Institute Jena — [2]GSI Helmholtz Centre for Heavy Ion Research, Darmstadt — [3]Friedrich Schiller University Jena — [4]Abbe Center of Photonics, Jena — [5]Physikalisch-Technische Bundesanstalt, Braunschweig

Step-up resonators are used to drive Paul traps at enhanced radio-frequency voltages; they additonally filter electrical noise and can reduce ion heating. Cryogenic setups typically offer improved passive temperature stability and thus result in inherently more stable trap drives. Despite these advantages, the permissible thermal load is limited and must be minimised. For these reasons, a high Q-factor becomes of paramount importance.

Exploiting the cryogenic environment, we are developing a step-up resonator based on the high-temperature superconductor YBCO. We aim at a high trap-drive frequency of up to 50 MHz for quantum logic spectroscopy with Be^{+} ions in the Lamb-Dicke regime. This demands an exceptionally high Q-factor to compensate for the high trap-drive frequency with a sufficiently large trap voltage for a given trap parameter q.

Q 27.19 Tue 17:00 Philo 1. OG

Buffer-Gas Positron Source for Loading a Dual-Frequency Paul Trap — •Mohammadreza Nematollahi[1,2,3], Vladimir Mikhailovskii[1,2,3], Natalija Sheth[1,2,3], Zhiheng Xue[5], K. T Satyajith[6], Christian Smorra[2,7], Gunther Werth[3], Hartmut Haffner[4], Ferdinand Schmidt-Kaler[3], Hendrik Bekker[1,2,3], and Dmitry Budker[1,2,3,4] — [1]Helmholtz-Institut Mainz, 55128 Mainz, Germany — [2]GSI Helmholtzzentrum fur Schwerionenforschung GmbH, 64291 Darmstadt, Germany — [3]QUANTUM, Institut fur Physik, Johannes Gutenberg-Universitat, 55128, Mainz, Germany — [4]Department of Physics, University of California, 94720-7300, Berkeley, USA — [5]University of Science and Technology of China, Heifie, China — [6]Delta Q, IMJ Institute of Research & Department of Physics — [7]Heinrich Heine University Dusseldorf, 40225 Dusseldorf, Germany

A dual-frequency trap has been proposed for confining antimatter to enable high-precision measurements [1]. This system is intended to co-trap positrons and antiprotons to form antihydrogen. In this work, we present an approach for generating low-energy bunches of positrons and delivering them into the trap. We simulated positron deceleration and bunching in a buffer-gas trap under various conditions. Our presented trap design and performance are informed by these simulations. We furthermore discuss several prospective methods to inject the positrons into the Paul trap.

1. N. Leefer, et al. Hyperfine Interact 238, 12 (2017)

Q 27.20 Tue 17:00 Philo 1. OG

The superconducting resonator Paul trap: status and developments — •Ruben B. Henninger, Elwin A. Dijck, Vera M. Schäfer, Devanarayanan Rajeeb Kumar, Sebastian Davidson, K Shreya Rao, Thomas Pfeifer, and José R. Crespo López-Urrutia — Max-Planck-Institut für Kernphysik, Heidelberg, Germany

Quantum logic spectroscopy of highly charged ions (HCIs) offers sensitivity to variations of fundamental constants and tests of bound state QED in extreme fields, while offering intrinsically low polarizability and therefore suppressed resonance shifts. This makes HCIs prime candidates for next generation clocks and precision tests. In order to accomplish this, a cryogenic trap setup that integrates a linear Paul trap into a superconducting RF resonator was developed. The first generation system provides intrinsic RF filtering, magnetic self shielding, and a stable quantization field with observed Ramsey coherence times above 200ms on a B field sensitive transition. In addressing residual AC field systematics, potential control limits and retrapping robustness, a redesigned trap and resonator employ optimized electrode geometry and upgraded cryogenics and optics. We present benchmark results from the working setup and initial data from the new platform, outlining a path to increased secular frequencies and lower magnetic systematics for HCI QLS.

Q 27.21 Tue 17:00 Philo 1. OG

Mechanical structure for alignment of a microfabricated cylindrical Penning trap — •Marek Prasse[1], Jan Schaper[1], Nikita Poljakov[1], Philipp Hoffmann[1], Julia Coenders[1], Juan Manuel Cornejo[2], Stefan Ulmer[3,4], and Christian Ospelkaus[1,5] — [1]Leibniz Universität Hannover — [2]Universidad de Cádiz, Spain — [3]Ulmer Fundamental Symmetries Laboratory, RIKEN, Japan — [4]Heinrich-Heine-Universität Düsseldorf, Germany — [5]Physikalisch-Technische Bundesanstalt, Braunschweig, Germany

As part of the BASE collaboration, we aim to contribute to CPT symmetry tests by high-precision (anti-)proton g-factor measurements[1,2]. We use a cryogenic multi-Penning trap and want to implement quantum logic spectroscopy techniques with $^9Be^+$ as cooling and logic ion. While optical sideband spectroscopy[3], ground-state cooling[4], and fast adiabatic transport[5] of single $^9Be^+$ ions has been achieved, a microfabricated cylindrical Penning trap ($d = 800\,\mu$m) will be added for ground-state cooling and spin-state detection of (anti-)protons by Coulomb coupling to $^9Be^+$. Particle confinement during ion-transport then requires a precise alignment with the magnetic field. We present a custom-made two-axis mechanical feedthrough suitable for the ≈ 40 kg weight of the experimental structure and with low heat flow to the cryogenic stages that has been designed and is in commissioning. [1]C. Smorra et al., Eur. Phys. J. Special Topics 224, 3055-3108 (2015) [2]J.M. Cornejo et al., New J. Phys. 23 (2021) [3]J.M. Cornejo et al., Phys. Rev. Res. 5 (2023) [4]J.M. Cornejo et al., Phys. Rev. Res. 6 (2024) [5]M. v. Boehn et al., Comms. Phys. 8 (2025)

Q 27.22 Tue 17:00 Philo 1. OG

Ground-state cooling of mixed-ion crystals in the intermediate Lamb-Dicke regime — •Sebastian Davidson, Elwin A. Dijck, Vera M. Schäfer, Ruben Henninger, Devanarayanan Rajeeb Kumar, Shreya K. Rao, José R. Crespo López-Urrutia, and Thomas Pfeifer — Max-Planck-Institut für Kernphysik, Heidelberg

Ground-state cooling of motional modes in mixed-species ion crystals is a key requirement for implementing quantum logic spectroscopy of highly charged ions (HCIs). Building on our demonstrated ground-state cooling of both single Be^+ ions and two-ion Be^+ crystals using a combination of continuous sideband cooling on higher-order sidebands and pulsed sideband cooling, we extend these techniques to a Be^+-Ar^{13+} two-ion crystal. Since our current trap operates in an intermediate Lamb-Dicke regime with η up to 0.7 for the mixed species crystal, we explore adapted cooling strategies that remain effective outside the Lamb-Dicke limit. We report our progress toward achieving ground-state cooling of axial modes of a Be^+-Ar^{13+} crystal under these conditions, including characterization and optimization of cooling sequences. These advances represent an essential step toward full quantum logic spectroscopy of HCIs and the high-precision tests of fundamental physics that they enable.

Q 27.23 Tue 17:00 Philo 1. OG

Monolithic frequency doubling cavities for Beryllium photoionization — •Anton J. Sterr, Magdalena Winkelvoss, Stepan Kokh, Sophia Dorra, Melina Gizewski, Finja Mayer, Maili Schube, José R. Crespo López-Urrutia, Thomas Pfeifer, and Vera M. Schäfer — Max-Planck-Institut für Kernphysik, Heidelberg

High-precision spectroscopy of optical transitions in Cf^{15+} and Cf^{17+} is a promising tool to search for variations of the fine structure constant [1]. To extract information from the californium ions, they are co-trapped with a singly charged beryllium logic ion.

Beryllium is ionized via two-photon absorption that requires a continuous wave laser source at 235 nm. Building on an existing approach [2], two monolithic cavities are designed to quadruple the frequency of an infrared source at 940 nm using periodically poled KTP and BBO crystals. We target at least 50 mW of UV power for a source of 1 W. To achieve optimum conversion efficiency, simulations for different cavity geometries are performed, taking thermal lensing effects into account. We present power measurements and locking performance of the first doubling stage.

[1] Kozlov, et al., Rev. Mod. Phys. 90, 045005 (2018)
[2] Hannig, et al., Rev. Sci. Instrum. 89, 013106 (2018)

Q 27.24 Tue 17:00 Philo 1. OG

Laser stabilization for high-precision spectroscopy of highly charged ions using an ultra-stable optical reference cavity — •Devanarayanan Rajeeb Kumar, Ruben B. Henninger, Elwin A. Dijck, Shreya Rao Kodancha, Sebastian Davidson, Vera M. Schäfer, José R. Crespo López-Urrutia, and Thomas Pfeifer — Max-Planck-Institut für Kernphysik, Heidelberg

Frequency metrology of clock transitions requires lasers of sub-hertz linewidth and exceptional frequency stability. For our work with highly charged ions, an ultra-stable, high finesse optical reference cavity was developed and is operated near room temperature to stabilize our lasers. Our ultra-low-expansion glass Fabry-Pérot etalon achieves a projected noise floor of 3.6×10^{-16} relative frequency uncertainty at 1 second - approaching that of state-of-the-art cryogenic silicon cavities. Additional stabilization techniques are implemented to suppress residual technical noise: Fiber-induced phase noise is actively canceled, laser power is stabilized to improve the fidelity of the cavity lock, and residual amplitude modulation is minimized through active control of the electro-optical modulator operating point. A frequency comb is then phase-locked to the cavity stabilized laser which enables low-noise frequency transfer to a spectroscopy laser. The resulting stabilized laser system should provide the stringent frequency stability and linewidth requirements needed for highly charged ion spectroscopy.

Q 27.25 Tue 17:00 Philo 1. OG

Characterising Atomic Hydrogen beam for precision spectroscopic experiment — •Surabhi Deshpande[1,2], Derya Taray[1], Vincent Weis[1], Patrick Schaile[1], Alexander Wilzewski[1], Omer Amit[1], Vitaly Wirthl[1], Theodor W. Hänsch[1,2], and Thomas Udem[1,2] — [1]Max Planck Institute for Quantum Optics (MPQ), Garching, Germany — [2]Department of Physics, Ludwig-Maximilians-Universität, Munich, Germany

Precision Spectroscopy of atomic hydrogen is a promising approach for measuring fundamental constants and testing QED due to the very simple structure of the atom. One of the most vital demands for such experiments is a stable source of atomic hydrogen and a method of precisely quantifying the atomic hydrogen population. In this poster, I will give an overview of the methods I attempted to characterise our atomic hydrogen beam in the 1S-3S Direct Frequency Comb Spectroscopy Experiment at MPQ. This includes Optical Emission Spectroscopy of the hydrogen plasma used to dissociate molecular hydrogen to atomic hydrogen, to compare optical emissions of atomic and molecular hydrogen, i.e., Balmer lines and Fulcher bands. In addition, a Calorimetric Wire Detector is being developed for in situ detection of atomic hydrogen. It is based on the resistance change of a very thin wire due to the heat released from the recombination of atomic hydrogen on its surface. I will present preliminary results from the Calorimetric Wire Detector for qualitative detection of atomic hydrogen.

Q 27.26 Tue 17:00 Philo 1. OG

High-resolution spectroscopy of $^{173}Yb^+$ ions — Jian Jiang[1], •Anna Viatkina[1,2], Saaswath JK[1], Martin Steinel[1], Melina Filzinger[1], Ekkehard Peik[1], Sergey Porsev[3], Marianna Safronova[3], Andrey Surzhykov[1,2], and Nils Huntemann[1] — [1]Physikalisch-Technische Bundesanstalt, 38116 Braunschweig, Germany — [2]Technische Universität Braunschweig, 38106 Braunschweig, Germany — [3]University of Delaware, Newark, Delaware 19716, USA

$^{173}Yb^+$ is a promising candidate for optical clocks, new physics searches, and quantum computing. However, to date, the electronic spectrum of $^{173}Yb^+$ remains poorly characterized due to its complexity.

Here, we report on efficient laser cooling, state preparation, and detection of a single trapped $^{173}Yb^+$ ion. The previously unobserved $^2S_{1/2} \to {}^2D_{3/2}$ electric quadrupole transition at 436 nm is coherently excited, and the isotope shift between $^{171}Yb^+$ and $^{173}Yb^+$ on this transition is determined with an uncertainty of 1.4 Hz. Using microwave spectroscopy, we resolve the hyperfine structure (HFS) of the $^2D_{3/2}$ state with a relative uncertainty below 10^{-8}.

Combining the HFS measurement data and our atomic structure calculations, we infer for ^{173}Yb a nuclear magnetic octupole moment $\Omega = -0.062(8)\,(\mathrm{b}\times\mu_N)$ with uncertainty reduced by more than two orders of magnitude compared to previous studies and determine hyperfine anomalies for the $^2S_{1/2}$ and $^2D_{3/2}$ states. These findings provide further information on the nuclear deformation and nuclear magnetization distribution of ytterbium.

Q 27.27 Tue 17:00 Philo 1. OG

Spectroscopy of the $^3[11/2]_{11/2}$ state in Yb^+ — •Mohamed Elshorbagy, Melina Filzinger, Martin Steinel, Jian Jiang, William Eckner, and Nils Huntemann — Physikalisch-Technische Bundesanstalt, Bundesallee 100, 38116 Braunschweig

The $^2S_{1/2} \to {}^2F_{7/2}$ electric octopole (E3) transition in Yb^+, with its exceptionally long excited-state lifetime and strong sensitivity to the fine-structure constant α, has been used to set the most stringent limits on its variations [PRL 130, 253001 (2023)]. These limits were derived from frequency comparisons against the $^2S_{1/2} \to {}^2D_{3/2}$ transition of the same ion. The precision achieved in the comparisons was limited by the large quantum projection noise resulting from the 53 ms lifetime of the $^2D_{3/2}$ state. A larger lifetime of several seconds is expected for the $^3[11/2]_{11/2}$ state that can be excited with laser radiation at 1094 nm from the $^2F_{7/2}$ state. We present the current status of our investigation and details of the corresponding probe laser system and interrogation sequence.

Q 27.28 Tue 17:00 Philo 1. OG

Characterization of an XUV Frequency Comb by Spectroscopy of Rydberg States — •Lennart Guth, Tobias Heldt, Anant Agarwal, Lukas Matt, Jan-Hendrik Oelmann, Nick Lackmann, Thomas Pfeifer, and José R. Crespo López-Urrutia — Max-Planck-Institut für Kernphysik, Heidelberg, Germany

We aim to use ultra-narrow transitions in highly charged ions (HCI) for novel frequency standards and fundamental physics studies. These transitions occur in the extreme ultraviolet (XUV), where narrow-bandwidth laser sources are unavailable. To address this, we built an XUV frequency comb that transfers coherence from a near-infrared (NIR) comb to the XUV via high harmonic generation (HHG) [1,2]. Using intra-cavity HHG, our system generates harmonics up to 40 eV with μW power in each order. We propose resonance-enhanced two-photon spectroscopy as a preliminary test towards spectroscopy of HCI, aiming to resolve individual teeth of our XUV comb and characterize its properties. In this approach, we excite neutral argon with one photon from a referenced 13th harmonic comb tooth to a Rydberg state, followed by ionization with a narrow-bandwidth continuous wave NIR laser. We then use velocity-map imaging to record the momentum of the released electrons, allowing us to identify the resonant Rydberg state. [1]Opt. Express 29, Issue 2, pp. 2624-2636 (2021) [2]Rev. Sci. Instrum. 95, 035115 (2024)

Q 27.29 Tue 17:00 Philo 1. OG

Internal conversion of Thorium-229 upon laser photoexcitation — •Marc Seitz[1], Daniel Moritz[2], Shengfeng Zeng[3], Francesca Calegari[1], Hannes Hübener[4], Umberto de Giovannini[4], Peter G. Thirolf[2], and Andrea Trabattoni[1] — [1]Center for Free-Electron Laser Science CFEL, Deutsches Elektronen-Synchrotron DESY, Notkestraße 85, 22607 Hamburg, Germany — [2]LMU München, Fakultät für Physik, 85748 Garching bei München, Germany — [3]Shenzhen Geim Graphene Center, Institue of Materials Research, Tsinghua Shenzhen International Graduate School, Tsinghua University, Shenzhen 518055, China — [4]Max Planck Institute for the Structure and Dynamics of Matter and Center for Free-Electron Laser Science, 22761 Hamburg, Germany

The low-energy isomeric transition of Thorium-229 and its dominant internal-conversion (IC) decay channel provide a unique platform for studying electron-nucleus interactions. Prior work indicates that the IC decay can be strongly influenced by the electronic environment. Here, we investigate the IC decay of Th-229 in the presence of an ultraviolet (UV) laser field. Thorium atoms are deposited on a high-bandgap surface to minimize hybridization with surface states. A UV laser resonantly promotes an electron to the lowest excited atomic state prior to nuclear decay. The resulting IC electrons are detected via time-of-flight spectroscopy. By comparing laser-on and laser-off measurements, we identify changes in the IC decay dynamics induced by photo-excitation. This constitutes, to our knowledge, the first experimental study of laser-perturbed Th-229m IC nuclear decay.

Q 28: Poster – Quantum Optics

QED and Cavity QED; Quantum Control; General Quantum Optics

Time: Tuesday 17:00–19:00 Location: Philo 2. OG

Q 28.1 Tue 17:00 Philo 2. OG

Few-Photon SUPER: Quantum emitter inversion via two off-resonant photon modes — •Quentin Richter[1], Jan Kaspari[1], Thomas Bracht[1], Leonid Yatsenko[2], Martin Axt[3], Arno Rauschenbeutel[4], Moritz Cygorek[1], and Doris Reiter[1] — [1]Condensed Matter Theory, TU Dortmund — [2]Institute of Physics, National Academy of Science of Ukraine — [3]Lehrstuhl für Theoretische Physik III, Universität Bayreuth — [4]Department of Physics, Humboldt-Universität zu Berlin

The interaction of a two-level system with a light field is one of the most important models in quantum optics.
In this contribution, we investigate a Jaynes-Cummings model with two non-degenerate, off-resonant, photon modes coupled to a two-level emitter. We find parameters, for which we can identify a multi-photon scattering leading to full inversion of the emitter while transferring off-resonant photons from one mode to the other.
The results can be understood as a quantized analogue of the off-resonant quantum control scheme known as Swing-UP of quantum EmitteR (SUPER). Unlike the SUPER scheme, which requires two off-resonant pulses to be present at all times, our model only needs one mode initially occupied and the other mode available to achieve full emitter inversion.
Our results enable novel schemes of photon control for quantum photonics.

Q 28.2 Tue 17:00 Philo 2. OG

Fractal geometry dictates the scaling of atom-photon bound states — •Florian Bönsel[1,2], Federico Roccati[1,3], and Flore Kunst[1,2] — [1]Max Planck Institute for the Science of Light, 91058 Erlangen, Germany — [2]Department of Physics, Friedrich-Alexander-Universität Erlangen-Nürnberg, 91058 Erlangen, Germany — [3]Dipartimento di Fisica e Chimica - Emilio Segre, Universita degli Studi di Palermo, I-90123 Palermo, Italy

We investigate the formation of atom-photon bound states in self-similar photonic lattices and derive a universal scaling law linking the localization length to the atom-bath detuning. By utilizing the heat-kernel representation of the Green's function, we circumvent the momentum-based approaches standard in waveguide QED. A key finding is that the scaling exponent is governed solely by the walk dimension, which characterizes classical anomalous diffusion, rather than the fractal or spectral dimension. This establishes a novel link between static quantum localization and dynamical transport. Numerical simulations on several fractals, such as Sierpinski and Vicsek graphs, confirm the derived results.

Q 28.3 Tue 17:00 Philo 2. OG

Cavity QED experiments and lasing with cold trapped Yb atoms — •Ke Li[1], Saran Shaju[1], Dmitriy Sholokhov[1], Simon B. Jäger[2], and Jürgen Eschner[1] — [1]Universität des Saarlandes, Experimentalphysik, 66123 Saarbrücken, Germany — [2]Universität Bonn, Physikalisches Institut, 53115 Bonn, Germany

Cavity quantum electrodynamics with cold atoms enables highly controlled interaction between atoms and photons, offering advanced applications in quantum technologies and fundamental science. In our research, 10^4 to 10^6 ^{174}Yb atoms are magneto-optically trapped, using the $^1S_0{-}^1P_1$ transition at 399 nm, inside a high-finesse cavity that couples to the $^1S_0{-}^3P_1$ intercombination transition at 556 nm. We have observed continuous lasing action in both single- and multi-mode emission [1]. When the atoms are magneto-optically trapped on the 556-nm transition, the collective strong coupling leads to complex atom-field dynamics and scattering phenomena, including vacuum Rabi splitting accompanied by additional fluorescence at atomic resonance [2]. Future research will be extended to interactions on the $^1S_0{-}^3P_0$ clock transition at 578 nm.
[1] H. Gothe et al., Phys. Rev. A 99, 013415 (2019).
[2] S. Shaju et al., Phys. Rev. A 112, 013705 (2025).

Q 28.4 Tue 17:00 Philo 2. OG

Controlling Quantum Gases in an Optical Cavity Through Continuous Measurement and Markovian Feedback — •Marcus Hofmann[1], Tobias Donner[2], Francesco Petiziol[1], and André Eckardt[1] — [1]Institut für Physik und Astronomie, Technische Universität Berlin, Hardenbergstraße 36, 10623 Berlin, Germany — [2]Institute for Quantum Electronics, ETH Zürich, 8093 Zürich, Switzerland

Ultracold quantum gases in optical cavities represent a powerful platform for exploring driven-dissipative quantum many-body physics. They have enabled the experimental observation of collective nonequilibrium effects induced by atom-light interactions, ranging from atomic self-organization and superradiance to nonequilibrium topological phases. In this project, we theoretically investigate a quantum-gas cavity QED setup endowed with the possibility to perform active feedback conditioned on the output of continuous measurements of the cavity field, as it has been realized in experiments at ETH Zürich. After developing a theoretical and numerical framework to describe the system, based on Wiseman-Milburn's formalism of Markovian quantum feedback, we explore the opportunities to control the state of the atoms and influence their ordering patterns by means of realistic measurement and feedback schemes.

Q 28.5 Tue 17:00 Philo 2. OG

Depletion dynamics of a Bose-Einstein condensate in a dissipative optical cavity — •Gage Harmon[1], Giovanna Morigi[1], Tom Schmit[1], and Simon Jäger[2] — [1]Saarland University — [2]University of Bonn

We study the depletion dynamics of a driven homogeneous Bose*Einstein condensate (BEC) strongly interacting with an optical cavity. Working in the bad-cavity regime, we eliminate the photonic degrees of freedom to obtain an effective atom-only master equation. Applying Bogoliubov theory, we derive the dynamics of the covariance matrix of the cavity-coupled atomic fluctuations. The resulting Lyapunov equation captures fluctuations arising from coherent and dissipative cavity-mediated interactions, as well as diffusive cavity shot noise. This system exhibits a self-organization (SO) phase transition and we analyze the depletion of the BEC in the normal (below threshold) and self-organized (above threshold) phases. Below threshold, we define an effective temperature for the cavity-coupled Bogoliubov mode and, in the weak-driving limit, derive an analytic expression consistent with previous results. Above threshold, the dominant depletion mechanism crosses over: near the SO transition, diffusion dominates, whereas deeper in the SO phase cavity-mediated atomic fluctuations prevail. We compare these cavity-induced depletion rates with those from short-range contact interactions obtained from Bogoliubov theory. With this we identify regimes in which cavity dissipation can, in principle, stabilize the condensate.

Q 28.6 Tue 17:00 Philo 2. OG

Generation of squeezed state superpositions of light with an atom-cavity system — •Maurizio Trigilia, Raphael Benz, Sebastian Alejandro Morales Ramirez, Micha Kappel, Daniel Reigel, Luis Weiss, Vincet Beguin, Leon Layer, Violet Ruf, and Stephan Welte for the QNN-Collaboration — 5. Physikalisches Institut, Center for Integrated Quantum Science and Technology and CZS Center QPhoton, Universität Stuttgart, Pfaffenwaldring 57, 70569 Stuttgart, Germany.

We present an experimental protocol that employs an atom-cavity system to generate superpositions of squeezed states of light [1]. To achieve this, a displaced squeezed light state is reflected from an atom-cavity system with the atom prepared in a superposition of a coupling and a non-coupling state. A subsequent measurement of the atom projects the light onto a squeezed Schrödinger-cat state of even or odd parity, depending on the measurement outcome. The scheme can be extended to generate optical Gottesman-Kitaev-Preskill states [1]. In a practical scenario, optical losses lead to a deterioration of the generated light states. We present a theoretical framework that incorporates these losses and apply it to a parameter regime that describes our novel atom-cavity system that is currently in the buildup phase. Our simulations allow us to estimate experimentally achievable state fidelities. We furthermore show simulations of the transport of atoms with an optical dipole trap from a 3D magneto-optical trap into our optical cavity. [1] J. Hastrup, U. Andersen, Phys. Rev. Lett. 128 (17), 170503 (2022).

Q 28.7 Tue 17:00 Philo 2. OG

Development of an experimental setup for quantum network experiments based on neutral atoms in an optical cavity — Raphael Benz, •Sebastián Alejandro Morales Ramírez, Micha Kappel, Daniel Reigel, Maurizio Trigilia, Luis Weiss, Vincent Beguin, Leon Layer, Violet Ruf, and Stephan Welte for the QNN-Collaboration — 5. Physikalisches Institut, Center for Integrated Quantum Science and Technology and CZS Center QPhoton, Universität Stuttgart, Pfaffenwaldring 57, 70569 Stuttgart, Germany.

The practical implementation of a quantum coherent network remains a pursued challenge across various hardware platforms. Cold neutral atoms trapped in a high-finesse optical cavity have proven to be a promising platform due to the efficient light-matter coupling and precise controllability of the system. Using optical tweezers to address individual atoms opens the possibility of extending this platform to versatile multi-qubit quantum network nodes. We present the progress and current status of our experimental setup with an emphasis on the planned vacuum system and the cavity design. We designed a 650-um-long cavity with a finesse of 40,000; it consists of two macroscopic super-polished mirrors, enabling single-atom cooperativities of C=5.2. To suppress mechanical vibrations, we developed a three-stage vibration isolation system. We discuss the mounting of this new setup. With our system, a wide range of experiments becomes feasible, including photon-mediated quantum information processing between intra-cavity atoms, the generation of highly entangled photonic cluster states, and the creation of optical GKP states.

Q 28.8 Tue 17:00 Philo 2. OG

Qubit entanglement via a single-mode Gaussian lateral defect Fabry-Perot cavity — •Ruolin Guan[1], Pengji Li[2], Xian Zheng[2], Vineesha Srivastava[3], Chenxi Ma[2], Eddy P. Rugeramigabo[2], Michael Zopf[2,4], Klemens Hammerer[1,3], and Fei Ding[2,4] — [1]Institut für Theoretische Physik, Leibniz Universität Hannover, Germany — [2]Institute of Solid State Physics, Leibniz University Hannover, Germany — [3]Institute for Quantum Optics and Quantum Information, Austrian Academy of Sciences, Innsbruck, Austria — [4]Laboratory of Nano and Quantum Engineering, Leibniz University Hannover, Germany

We propose a chip-compatible DBR Fabry-Perot cavity with a lateral Gaussian defect that allows two InAs/GaAs quantum dots to couple to a single optical mode. Using full-wave FDTD simulations and a single-mode Green-function mapping, we derive the collective decay rate and the exchange coupling. These parameters can be tuned continuously via the relative phase, enabling transitions between superradiant, subradiant, and dispersive regimes within the same device. We further show that the second-order correlation function serves as an experimentally accessible entanglement witness, and demonstrate two prototypes: a superradiant single-photon source and a dissipatively protected quantum phase gate.

Q 28.9 Tue 17:00 Philo 2. OG

Design and simulation of circular Bragg grating cavities for enhanced emission and spin readout of silicon C centers — •Junchun Yang[1], Alessandro Puddu[1,2], Shuyu Wen[2], Sourav Dev[1], Shengqiang Zhou[2], Yonder Berencén[2], and Kambiz Jamshidi[1] — [1]TU Dresden, Dresden, German — [2]Helmholtz-Zentrum Dresden-Rossendorf, Dresden, Germany

Color centers are optically addressable atomic-scale defects in solid-state hosts that enable the coherent control of individual spins and the generation of quantum light. Among them, silicon-based color centers are particularly attractive owing to technological maturity, CMOS compatibility, and scalability. Recently, we demonstrated optically detected magnetic resonance (ODMR) of an ensemble of silicon C centers, revealing the energy-level structure and spin-selective optical transitions. Here, we aim to enhance both the emission rate and photon collection efficiency of the silicon C center through integration with a photonic cavity. A circular Bragg gratings (CBG) cavity provides a moderate Purcell factor while its rotational symmetry ensures efficient upward coupling for any in-plane dipole. Additionally, the broad cavity linewidth enables spectral overlap without post-fabrication tuning. In this work, we use finite-difference time-domain (FDTD) simulations in Lumerical to design a CBG cavity, achieving a theoretical Purcell enhancement of 11 and a collection efficiency of 40%.

Q 28.10 Tue 17:00 Philo 2. OG

Single-pulse SUPER — •Jonas Köglmayr[1], Paul Constantin Alexander Hagen[1], Doris Reiter[2], Moritz Cygorek[2], and Vollrath Martin Axt[1] — [1]Lehrstuhl für Theoretische Physik III, Universität Bayreuth, Germany — [2]Condensed Matter Theory, TU Dortmund, Germany

Optical control is essential for efficient single-photon generation in quantum technology applications. The Swing-UP of Quantum EmitteR population (SUPER) mechanism is an approach to coherently control a quantum emitter by using two detuned laser pulses. Recently, SUPER has been extended to a fully quantized picture where two detuned cavity modes replace the pulses. Here we consider a different variation of SUPER where a single detuned laser pulse drives a quantum emitter coupled to an off-resonant cavity. As only one laser is needed compared to the original proposal, we term this the Single-pulse SUPER scheme. Using a dressed-state picture we explain the numerically observed dynamics and resonance conditions. We demonstrate that a high population inversion is theoretically feasible even when realistic cavity losses and emitter relaxation processes are taken into account. In addition to preparing the emitter in the upper state a photon is stored in the cavity. Thus, after completing the preparation a single photon is emitted by de-exciting the emitter and a second spectrally distinct single photon can be released from the cavity. These insights suggest that this system could be a source of two distinct single photons paving the way for a broad range of photonic applications.

Q 28.11 Tue 17:00 Philo 2. OG

Interacting bosonic system — •Margherita Valenza[1,2], Flore K. Kunst[1,2], and Anton Montag[1,2] — [1]Max Planck Institute for the Science of Light, Staudtstraße 2, 91058 Erlangen, Germany — [2]Department of Physics, Friedrich-Alexander Universitat Erlangen-Nurnberg, Staudtstraße 7, 91058 Erlangen, Germany

The collective behaviour of many-body systems is one of the main interests of contemporary quantum physics, particularly within the frameworks of nonlinear optics and Bose-Einstein condensate. In our case, we explore a tight binding model of coupled cavities array where there is the competition between coherent and incoherent effects. From the perspective of open quantum system, this interplay can create robust quantum resources and new phases of matter can arise as a consequence of the nontrivial behaviour of the steady state. As a consequence, the time-dependent simulations of the coherence matrix reveal a nontrivial effect in the regime of parameter that could be unstable in the absence of dissipation, but becomes stable due to cavity decay. These results highlight a nontrivial interplay between hopping, nonlinear drive and dissipation in engineered photonic systems.

Q 28.12 Tue 17:00 Philo 2. OG

Re-entrant phase transition in many-body Cavity QED — •Tom Schmit[1], Laura Batini[2], Justyna Stefaniak[3], David Baur[3], Gabriele Natale[3], Fabian Bennati Weis[3], Nicolò Defenu[2], Tobias Donner[3], and Giovanna Morigi[1] — [1]Theoretische Physik, Universität des Saarlandes, 66123 Saarbrücken, Germany — [2]Institut für Theoretische Physik, Eidgenössische Technische Hochschule Zürich, Wolfgang-Pauli-Straße 27, 8093 Zürich, Switzerland — [3]Institute for Quantum Electronics, Eidgenössische Technische Hochschule Zürich, Otto-Stern-Weg 1, 8093 Zürich, Switzerland

A driven quantum gas of atoms in an optical cavity offers a powerful platform for exploring the equilibrium properties of long-range interacting systems. The interplay between the external drive, quantum fluctuations, and the cavity-mediated long-range interaction can lead to the formation of stable self-organized structures. When the system is transversaly driven with a laser that is blue-detuned from the atomic transition, an intriguing behaviour is observed: as the drive strength increases, the system first undergoes a transition from the normal phase to a self-organized phase at a critical threshold, but then, at a higher threshold, exhibits a *re-entrant phase transition* back to the normal phase, as experimentally demonstrated[1]. In this work, we develop a Ginzburg-Landau model for the transition between the normal and self-organized phases, based on a mean-field ansatz. This framework allows us to identify the mechanisms that stabilize and destabilize the self-organized state, giving the re-entrant behaviour.

Q 28.13 Tue 17:00 Philo 2. OG

Heralded generation of atom-photon entanglement — •Pau Farrera[1,2], Gianvito Chiarella[1], Tobias Frank[1], Leart Zuka[1], and Gerhard Rempe[1] — [1]Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Straße 1, 85748 Garching, Germany — [2]Munich Center for Quantum Science and Technology (MCQST), Schellingstr. 4, D-80799 München

Reducing inefficiency and infidelity errors in quantum communication operations is essential in order to implement advanced quantum communication schemes. While heralding photonic quantum states at their reception allows to track and reduce propagation and measurement errors, heralding the generation of such states allows to immediately and faithfully react upon source errors. Here we implement a new method to track and mitigate errors in the generation of atom-photon entanglement. The method is based on the cascaded two-photon emission of a single atom into two crossed fiber cavities. The polarization state of one photon is entangled with the spin degree of freedom of the atom, and the second photon heralds the successful entanglement generation. We show that heralding improves the atom-photon entanglement in-fiber efficiency and fidelity to 68(3)% and 87(2)%, respectively. We highlight the potential of our source for noise-limited long-distance quantum communication by extending the range for constant fidelity or, alternatively, increasing the fidelity for a given distance.

Q 28.14 Tue 17:00 Philo 2. OG

Self-consistent matter description of the Dicke-Ising chain — •Jonas Leibig, Max Hörmann, Anja Langheld, Andreas Schellenberger, and Kai Phillip Schmidt — Department of Physics, Staudtstraße 7, Friedrich-Alexander-Universität Erlangen-Nürnberg, Germany

The Dicke-Ising model admits an exact thermodynamic limit mapping to a self-consistent effective matter Hamiltonian [2], where the photon mode enters only as an effective transverse field. In our recent work [1], we apply this mapping and solve the resulting self-consistent spin model using a high-precision NLCE+DMRG approach. This allows us to obtain the thermodynamic-limit phase diagram in one dimension, resolving the ferromagnetic multicritical point with an accuracy of 10^{-4}, and confirm the narrow antiferromagnetic superradiant phase.

References

[1] J. Leibig, M. Hörmann, A. Langheld, A. Schellenberger, and K. P. Schmidt, "Quantitative NLCE+DMRG approach for 1D Dicke-Ising models via self-consistent matter Hamiltonians', *to be published* (2025).
[2] J. Román-Roche, Á. Gómez-León, F. Luis, and D. Zueco, "Linear response theory for cavity QED materials at arbitrary light–matter coupling strengths", *Physical Review B* **111**, 035156 (2025).

Q 28.15 Tue 17:00 Philo 2. OG

An atomic tweezer array with strong cavity coupling — •Johannes Schabbauer[1,2], Stephan Roschinski[1,2], Franz von Silva-Tarouca[1,2], Damien Bloch[1,2], and Julian Leonard[1,2] — [1]Atominstutut, Vienna Center for Quantum Science and Technology (VCQ), TU Wien, Austria — [2]Institute of Science and Technology Austria (ISTA), Klosterneuburg, Austria

The efficient generation of many-body entangled states is a key challenge for enabling useful quantum technologies. In some experiments with ultra-cold neutral atoms, entanglement can be created via local processes, like Rydberg or dipolar interactions. However, if one wants to efficiently create many-body states with non-local entanglement, like GHZ-states, having a process that is inherently non-local is desired. We realize this via photon-mediated interactions, by strongly coupling atoms to an optical cavity. In our experiment we achieve a very efficient light-matter interface by using a high-finesse fiber cavity with a Purcell factor of 160. For strong confinement within the cavity mode, the atoms are trapped in an array of optical tweezers. The tweezers enable site-resolved fluorescence imaging, and we use the cavity transmission for non-destructive readout of the atomic state. To control the atom-cavity coupling, we move the position of each tweezer with respect to the cavity mode. In addition, we will tune the cavity-mediated interactions of each atom individually via local lightshifts. This toolbox enables use to prepare and study many-body entanglement within the atomic array.

Q 28.16 Tue 17:00 Philo 2. OG

Characterisation of perovskite quantum dots interfaced with a high-finesse cavity — •Svenja Müller[1], Amrutha Rajan[2], Gabriele Raino[2], Maksym Kovalenko[2], and David Hunger[1] — [1]Physikalisches Institut, Karlsruher Institut für Technologie, 76131 Karlsruhe, Germany — [2]Department of Chemistry and Applied Biosciences, Institute of Inorganic Chemistry, ETH Zurich, 8093 Zurich, Switzerland.

Perovskite Quantum dots (PQDs) exhibit promising optical characteristics like a narrow emission line-width, a strong oscillator strength, and high quantum yield. Interfacing PQDs with an optical cavity gives the possibility controllably enhance light-matter interactions via the Purcell effect. As a first step, we integrate PQDs in a tunable, fiber-based microcavity to realize a highly coherent emitter of single photons. This may enable the generation of indistinguishable photons at room temperature, which can be useful in quantum network experiments. As a second step, we aim to reach the regime of strong coupling by integrating large PQDs with increased oscillator strength into a high-finesse cavity. In the strong coupling regime, the coupling of the emitter to the cavity is faster than the dephasing and cavity decay rates, offering insights into coherent light-matter interactions.

Q 28.17 Tue 17:00 Philo 2. OG

Spontaneous emission in the presence of a hemispherical mirror — •Yannick Weiser, Tommaso Faorlin, Lorenz Panzl, Giovanni Cerchiari, and Rainer Blatt — Universität Innsbruck, Institut für Experimentalphysik, Technikerstraße 25, 6020 Innsbruck, Austria

We control the spontaneous emission of a trapped $^{138}Ba^{+}$ ion by back reflecting the fluorescence light of the ion to itself via a mirror. Due to this retro reflection, the emitted photon interferes with itself, which enhances, or suppresses the observed emission rate, depending on the ion-mirror distance. Previous systems used lenses to guide the fluorescence light to a planar mirror. This approach limits the controllable portion of solid angle. Instead in a new system, called the Panopticon setup, the ion is placed in the center of curvature of a hemispherical mirror with NA = 0.996.

Future experiments enabled by the high-NA control of the mirror will investigate the alteration of the spontaneous emission rate in the presence of the hemispherical mirror. A suppression down to 6% of the natural rate of spontaneous emission is predicted in a realistic scenario. Since this effect on the emission rate is wavelength dependent, the natural branching ratio is influenced by the presence of the hemispherical mirror in a wavelength dependent way.

A hemispherical mirror spanning a large large part of the solid angle may also reshape the spatial distribution of emitted fluorescence light, enabling one to tailor the emission towards a preferred direction.

Q 28.18 Tue 17:00 Philo 2. OG

Spatially-varying spin-photon coupling in the antiferromagnetic Dicke-Ising model — •Anja Langheld and Kai Phillip Schmidt — Department of Physics, Friedrich-Alexander-Universität Erlangen-Nürnberg

The Dicke-Ising model is a paradigmatic model for studying light-matter interactions. For antiferromagnetic Ising interactions, the model reveals a rich quantum phase diagram, including a phase with coexisting antiferromagnetic and superradiant order. However, this phase was found to be notably restricted in its extent, in particular in one dimension [1]. As a potential mechanism to expand this phase, we study spatially-varying spin-photon couplings in the Dicke-Ising model beyond the long-wavelength approximation. For this, we employ a specialized quantum Monte Carlo (QMC) method tailored to Dicke-Spin systems [1], allowing us to accurately pinpoint all quantum phase transitions.

[1] A. Langheld et al., Phys. Rev. B 112, L161123 (2025)

Q 28.19 Tue 17:00 Philo 2. OG

(Quasi-)continuous-wave superradiant Lasers — •Max Hachmann, David Nak, and Andreas Hemmerich — Institut für Quantenphysik, Universität Hamburg, Deutschland

Superradiant Lasers are promising candidates for next-generation light sources with ultralow bandwidth, suitable as read-out tools for passive optical atomic clocks or active frequency standards themselves. Their main advantages are the possible utilization of ultranarrow transitions for lasing and a strongly suppressed dependence on an eigenfrequency of the laser cavity. However, achieving the full potential of sub-natural linewidths requires continuouswave operation, as pulsed emission is Fourier-limited.

We report the successful operation of a quasi-continuously emitting superradiant laser using cold bosonic calcium-40 atoms as the gain medium. These atoms are cooled in a bichromatic magneto-optical trap and loaded into a magic-wavelength one-dimensional optical lattice prepared inside a cavity. After incoherent population of the upper laser state, pulsed superradiant emission on the 370 Hz intercombination line was realized. We extended this scheme to continuously pump the decayed atoms back into the upper laser state, prolonging the lasing by up to three orders of magnitude until too many atoms are lost due to heating. We could observe a Fourier-limited but sub-natural emission linewidth of less than 100 Hz and confirmed suppressed cavity influence with a cavity pulling factor of only 0.5 %.

Q 28.20 Tue 17:00 Philo 2. OG

Optimizing ancilla-assisted shortcuts to adiabaticity — •Giorgio Anfuso[1,4], Emma King[2], Luigi Giannelli[1,3,4], Giuseppe Falci[1,3,4], and Giovanna Morigi[2,5] — [1]Dipartimento di Fisica e Astronomia "Ettore Majorana", Universitá di Catania, Via S. Sofia 64, 95123, Catania, Italy — [2]Theoretische Physik, Universität des Saarlandes, D-66123 Saarbrücken, Germany — [3]CNR-IMM, UoS Universitá, 95123, Catania, Italy — [4]INFN Sez. Catania, 95123 Catania, Italy — [5]Center for Quantum Technologies (QuTe), Saarland University, Campus, 66123 Saarbrücken, Germany

Adiabatic protocols are valued for their intrinsic robustness to control imperfections, but their long evolution times make them susceptible to decoherence. Shortcuts to adiabaticity (STA) describe techniques used to reach the same target states more rapidly, thereby mitigating this exposure to noise. Recent works have shown that STA can be implemented in driven two-level systems by coupling to an ancillary quantum system, achieving substantial suppression of diabatic transitions. We identify further opportunities for performance enhancement in this ancilla-assisted protocol by optimizing the driving, coupling strength, and interaction orientation. By dynamically controlling these time-dependent knobs, we use quantum optimal control methods to determine the extent to which quantum ancillas can be further exploited to improve fidelity, robustness, and overall speed of state transfer. Our results take a step toward better understanding the performance benefits of quantum ancilla-assisted STA and clarify the extent to which optimized schemes can surpass fixed-parameter schemes.

Q 28.21 Tue 17:00 Philo 2. OG

Experimental Control with QUDI towards manipulation of single C-13 nuclear spin — •Michel Wolf, Jeremias Resch, Ioannis Karapatzakis, Wolfgang Wernsdorfer, and David Hunger — Karlsruher Institut für Technologie

Quantum networks depend on an interface between photons and long-lived spin degrees of freedom. A promising platform is the tin-vacancy centers in diamond, which offers long electron spin lifetimes due to its strong spin-orbit coupling. To achieve storage times exceeding the communication time between two nodes, even more long-lived nuclear spin degrees need to be coherently addressed. Both the manipulation of these optically addressable spin-qubits and the implementation of quantum network protocols rely on pulse sequences. Therefore, a practical challenge to overcome is the generation of such pulse sequences efficiently as well as the integration to the experimental control orchestrating the required hardware. In this work, we demonstrate the integration of QUDI as a control framework to realize improved and flexible manipulation of a single C-13 nuclear spin.

Q 28.22 Tue 17:00 Philo 2. OG

Quantum dynamical transitions when the corresponding classical phase space has a separatrix: extension of the QKNH theorem beyond double wells — •Peter Stabel and James Anglin — RPTU Kaiserslautern-Landau, 67663 Kaiserslautern

In classical Hamiltonian systems with a slowly time-dependent parameter, adiabatic approximations break down near a separatrix, where a constant-energy contour splits into separate contours, forcing the system to choose which contour to follow. The Kruskal-Neishtadt-Henrard (KNH) theorem relates the probabilities of such post-adiabatic dynamical transitions to the growth rates of the phase space areas enclosed by the different adiabatic contours. Quantum mechanically, in contrast, adiabaticity can persist at energies where it breaks down classically, through dynamical tunneling. Since the adiabatic and classical limits do not commute, the quantum-classical correspondence for dynamical transitions, where a separatrix is crossed in the classical system, is non-trivial. We recently demonstrated that a quantum version of the KNH theorem (QKNH) holds. We derived the QKNH theorem for a time-dependent double-well system, where the nearly degenerate levels below the potential barrier split due to tunneling through the barrier. We demonstrate that these findings are not restricted to double-well systems. We investigate the dynamical transitions of a general quantum pendulum where the crossings of adiabatic energy levels are avoided due to above-barrier reflection.

Q 28.23 Tue 17:00 Philo 2. OG

Frequency Conversion of Solid-State Sources for Telecom-Band Quantum Networking — •Chao Gao, Fabrice von Chamier Gliszczinski, Elnaz Bazzazi, Roger Alfredo Kögler, Esteban Gomez Lopez, Hala Said, and Oliver Benson — Institut für Physik der Humboldt-Universität zu Berlin

Solid-state quantum emitters are promising systems for quantum communication, yet their emission wavelengths are typically far from the low-loss telecom band required for efficient transmission in quantum networks. Frequency conversion bridges this mismatch. Our previously published two-step architecture (Optics Express 33, 21650 (2025)) provides a low-noise approach for translating photons from efficient non-telecom solid-state emitters toward the telecom regime.

Here, we examine the performance of one stage of that two-step converter–a difference-frequency generation interface in a periodically poled lithium niobate waveguide–designed to be compatible with non-telecom photons from semiconductor quantum dots. We characterize its efficiency and noise behavior. This work provides a frequency-conversion interface that mediates between stationary solid-state emitters and telecom-compatible quantum networks.

Q 28.24 Tue 17:00 Philo 2. OG

Engineering of maximally entangled orbital angular momentum states via path identity — •Richard Bernecker[1,2], Baghdasar Baghdasaryan[3], and Stephan Fritzsche[1,2] — [1]Institute for Theoretical Physics, Friedrich Schiller University Jena, Fröbelstieg 1, 07743 Jena, Germany — [2]Helmholtz Institute Jena, Fröbelstieg 3, 07743 Jena, Germany — [3]Institute of Applied Physics, Friedrich Schiller University Jena, Albert-Einstein-Str. 6, 07745 Jena, Germany

Cutting-edge quantum technologies lean on sources of high-dimensional entangled states (HDES) that reliably prepare high-fidelity target states. The idea to overlap photon paths from distinct but indistinguishable sources was recently introduced for the creation of HDES, known as entanglement by path identity. In this regard, the use of orbital angular momentum (OAM) modes is promising, as they offer a high-dimensional and discrete Hilbert space to encode information. While entanglement by path identity with OAM has been verified experimentally, a detailed investigation of how the OAM distribution of photon pairs can be engineered to maximize the entanglement is lacking. We address this gap and identify an optimal dimensionality for maximally entangled states (MESs) when the spatial engineering of the pump beam and the path identity approach are combined. Our theoretical study reveals notable limitations for the fidelity of high-dimensional target states. We also establish the equivalence of entangled biphoton states pumped by a spatially engineered beam and generated via path identity.

Q 28.25 Tue 17:00 Philo 2. OG

Multi-Wavelength Stellar Intensity Interferometry with a Telescope Array — •Iurii Datii[1], Oren Ironi[2], Nick Konidaris[3], Sagi Ben-Ami[2], and Joachim von Zanthier[1] — [1]Quantum Optics and Quantum Information, FAU Erlangen, Germany — [2]Weizmann Institute of Science, Rehovot, Israel — [3]Carnegie Observatories, Pasadena, USA

Recent progress in single-photon detection has renewed interest in stellar intensity interferometry. We present a concept for an HBT (Hanbury Brown Twiss) experiment combining a spectrograph with a telescope array to achieve a broad optical bandwidth. The spectrograph minimizes light loss from filtering, while the SPAD Lambda detector (with 320 linearly arranged pixels) covers $\Delta\lambda = 0.2$ nm per pixel, greatly improving the signal-to-noise ratio.

The setup employs twenty 60 cm telescopes, offering a large effective collecting area at about 10% the cost of a single telescope with a diameter of 2.7m. This compact, cost-efficient array enables affordable large-baseline optical intensity interferometry and precise measurements of stellar diameters.

Q 28.26 Tue 17:00 Philo 2. OG

Tomographic reconstruction of free-electron quantum states — •Hao Jeng[1,2] and Claus Ropers[1,2] — [1]Department of Ultrafast Dynamics, Max Planck Institute for Multidisciplinary Sciences, D-37077 Göttingen, Germany — [2]IV. Physical Institute, University of Göttingen, D-37077 Göttingen, Germany

Quantum state tomography is a fundamental and essential technique in every branch of quantum optics, this being true also for the newly emerging field of free-electron quantum optics. In this contribution, we describe several algorithms for reconstructing quantum states of swift electrons, using maximum likelihood estimation, Bayesian inversion, and deep learning. We apply these algorithms to experimental data previously recorded for an attosecond electron pulse-train to retrieve the density matrix and to analyse its physical properties. Based on the reconstructed quantum state, we obtain pulse-durations of about 245as and predict a degree of coherence of 36 per cent for radiations and excitations produced by these electrons.

Q 28.27 Tue 17:00 Philo 2. OG

Hanbury Brown-Twiss interference of electrons in free space — •Florian Fleischmann[1], Mona Bukenberger[1,2], Anton Classen[1,3], Marc-Oliver Pleinert[1], and Joachim von Zanthier[1] — [1]Friedrich-Alexander- Universität Erlangen-Nürnberg, 91058 Erlangen, Germany — [2]Freie Universität Berlin, Berlin, Germany — [3]University of Utah, Salt Lake City, USA

We investigate the spatial second-order correlation function of two electrons originating from two nanotips in a Hanbury Brown-Twiss like setup. First, we consider semi-classically the effects of the Pauli exclusion principle and Coulomb repulsion on the expected correlation pattern. This is followed by a quantum-mechanical treatment of the problem, where we separate the system into relative and center-of-mass coordinates in analogy to the Hydrogen atom ansatz. While the center-of-mass system is described as a free particle, the relative system contains the Coulomb scattering process which translates into an effective one-particle problem. We expand the respective initial state of the electrons in the eigenstates of the corresponding Hamiltonian and evolve the system in time. After the scattering process, the function is evaluated in the far field. We present the formal solution of the problem and discuss the current state of the numerical investigations.

Q 28.28 Tue 17:00 Philo 2. OG

Towards counterpropagating frequency converters in x-cut TFLN — •Nivedita Vishnukumar, Laura Bollmers, Michael Rüsing, Harald Herrmann, Laura Padberg, and Christine Silberhorn — Paderborn University, Integrated Quantum Optics, Institute for Photonic Quantum Systems (PhoQS), Warburger Str. 100, 33098 Paderborn, Germany

Frequency converters are mainly used to bridge the spectral mismatch between different photonic systems, for example converting wavelengths used for quantum memories to telecom band. Thin-film lithium niobate (TFLN) is a viable platform due its high nonlinear coefficient, high index contrast, and poling capabilities for $\chi2$ nonlinear processes. Conventional frequency converters work on co-propagating interactions, where pump, signal, and idler waves travel in the same direction. Counterpropagating frequency converters are less explored and are particularly interesting because such a process can generate separable quantum states with different bandwidths, eventually being helpful in secure quantum computation. The large phase mismatch from the counterpropagating photons is compensated through quasi phase matching (QPM) and this requires ultrashort poling periods of TFLN in sub-micrometer orders. We investigate through simulation and fabrication the feasibility of implementing counterpropagating frequency converters on x-cut TFLN. Our efforts focus on optimizing device geometry and exploring nanometer-scale poling techniques to enable efficient nonlinear interactions on this platform.

Q 28.29 Tue 17:00 Philo 2. OG

Optimization of electrode design for future interaction-free-measurements with electrons — •FABIAN BAMMES[1], FRANZ SCHMIDT-KALER[1], NILS BODE[1], MICHAEL SEIDLING[1], ROBERT ZIMMERMANN[1], LARS RADTKE[1], JUSTUS WALTHER[1], and PETER HOMMELHOFF[1,2] — [1]Erlangen-Nürnberg (FAU), Staudtstrasse 1, D-91058 Erlangen, Germany — [2]Fakultät für Physik, Ludwig-Maximilians-Universität, D-80799 München, Germany

True single particle observation of biological samples at atomic resolution is currently limited by radiation damage and low sample contrasts. Both challenges can be overcome with novel observation techniques established in the optical regime, namely interaction-free measurements (IFM) reducing damage, -and multi-pass experiments optimizing low sample contrast. Transferring detection from photons to charged particles potentially increases lateral resolution. IFM with electrons will be realized in a quantum electron microscope (QEM) employing three individual electron-optical components, namely electron guide, splitter and beam resonator. All three of them have been demonstrated individually with planar electrostatic electrode arrays using the auto-ponderomotive principle. We operated at primary energies of up to 9.5keV for guiding, 1.7keV for splitting and 50eV for resonating electron beams. Current work focuses on deceleration on-a-chip, as well as the geometric optimization to reduce losses and improve the pseudo-potential symmetry.

Q 28.30 Tue 17:00 Philo 2. OG

Bohmian Trajectories in a Double Slit Experiment — •Ozan Nacitarhan[1,2,3], Carlotta Versmold[1,2,3], Florian Huber[1,2,3], Lukas Knips[1,2,3], Jan Dziewior[1,2,3], Eun Mi Kim[1,2,3,4], and Harald Weinfurter[1,2,3] — [1]Fakultät für Physik, Ludwig-Maximilians-Universität, München, Germany — [2]Munich Center for Quantum Science and Technology, München, Germany — [3]Max-Planck-Institut für Quantenoptik, Garching, Germany — [4]Department of Physics, Korea Advanced Institute of Science and Technology, Daejeon, Republic of Korea

Bohmian mechanics provides a realist interpretation of quantum mechanics in terms of particles with definite positions, evolving along well-defined trajectories. In turn, this concept requires non-local effects, allowing instantaneous changes of the trajectory due to remote modifications of the setup.

Bohmian trajectories have been reconstructed via weak measurements and have been shown to agree with predicted ones in stationary setups. In our experiment, we record the trajectories of a photon in a double slit interferometer using direct phasefront measurements and additionally implement time-dependent which-way marking and delayed-choice quantum erasure to explore the theory*s non-locality. By initially entangling the double slit photon with a second photon, we are able to analyze the which-way-information and observe changes in the evolution of the interfering photon in dependence on the observation of the second photon. Thereby examining the need and consequences of the non-local mechanism in Bohmian mechanics.

Q 28.31 Tue 17:00 Philo 2. OG

Guiding electrons in rotating saddle potentials — •Franz Schmidt-Kaler[1], Johannes Illmer[1], Fabian Bammes[1], and Peter Hommelhoff[1,2] — [1]Department Physik, Friedrich-Alexander-Universität Erlangen-Nürnberg (FAU), 91058 Erlangen — [2]Fakultät für Physik, Ludwig-Maximilians-Universität, D-80799 München, Germany

We aim at achieving true single particle detection of radiation-sensitive samples by interaction-free measurement (IFM) within a quantum electron microscope (QEM). The principle, already established with photons, can benefit in lateral resolution by switching to electrons. A challenge remains the creation of the required electron-optical elements, namely guide, splitter and resonator. We present a novel guiding concept in which 3D printing enables the creation of rotating saddle potentials. We achieve trap depths of 11eV and show guiding of up to 20keV electrons in simulation and measurement, whilst recording the 1st stability regime. The concept promises simple adoption and could potentially find use in ion trap shuttling, as well as electron optics and localized radiation therapy.

Q 28.32 Tue 17:00 Philo 2. OG

Interaction-induced topological phase transition via spatially selective nonlinearity in photonic honeycomb lattices — •Bashar Karaja, Michael Fleischhauer, and Christina Jörg — RPTU Kaiserslautern, Kaiserslautern, Germany

We study interaction-induced topological phase transitions (IDTPs) in a photonic Haldane[1] lattice with spatially modulated Kerr nonlinearity. By applying nonlinear terms of opposite signs on A and B sublattices, we create an intensity-dependent effective mass term that can lead to local topology changes dynamically with the strength of the optical field. IDTPs appear only when the optical field exceeds specific thresholds: an inverse participation ratio (IPR) $>=$ 0.004, indicating sufficient spatial localization of the field, and a population measure p5, defined as the summed intensity on the five brightest sites. Stronger nonlinearity opens a larger induced band gap, increasing the lifetime, the spatial confinement, and the edge-state propagation length of the topological phase. Because the nonlinearity togehther with spatially non-uniform laser intensity breaks lattice periodicity, we characterize local topology using the spectral localizer, which remains valid in strongly inhomogeneous systems. To enhance experimental viability, we propose a pump-probe scheme in which a strong pump beam generates the nonlinear potential and a weak probe excites edge states. Higher pump power yields smoother, more stable effective potentials and longer-lived induced topological phases.

[1]Haldane, F.D. (1988). Model for a quantum Hall effect without Landau levels. Phys. Rev. Lett., 61(18), 2015-2018.

Q 28.33 Tue 17:00 Philo 2. OG

Towards an all-optical phase shifter based on integrated waveguides immersed in hot atomic vapor — •Annika Belz[1], Alexandra Köpf[1,2], Benyamin Shnirman[1,2], Xiaoyu Cheng[1], Hadiseh Alaeian[3], Harald Kübler[1], Robert Löw[1], and Tilman Pfau[1] — [1]5. Physikalisches Institut and Center for Integrated Quantum Science and Technology, Universität Stuttgart, Germany — [2]Institut für Mikroelektronik Stuttgart (IMS-Chips), Stuttgart, Germany — [3]Departments of Electrical & Computer Engineering and Physics & Astronomy, Purdue University, West Lafayette, USA

The combination of thermal atomic vapor with nanophotonics provides a unique testbed for the manipulation of atom-photon and atom-atom interactions. While benefitting from strong miniaturization, integration and scalability, we can furthermore enhance the atom-light interaction by engineering the waveguide structures correspondingly.

Using this platform, we want to realize an all-optical phase shifter in the telecom wavelength on the few photon level, which is a fundamental building block for e.g. photonical quantum computing.

This device leverages the effective refractive index change in rubidium for 1529nm light, corresponding to the excitation from the intermediate $5P_{3/2}$ state to the $4D_{5/2}$ state, induced by 780nm light, exciting the atoms from the $5S_{1/2}$ ground state to the $5P_{3/2}$ intermediate state.

We present first free-space measurements using a Michelson interferometer characterizing the three-level system and first designs towards the integration.

Q 28.34 Tue 17:00 Philo 2. OG

Sub-Doppler absorption lines at telecom wavelength in hot ^{87}Rb vapor — •Inna Kviatkovsky[1], Lucas Pache[1], Leonid Yatsenko[2], Viola-Antonella Zeilberger[1], Philipp Schneeweiss[1], Jürgen Volz[1], and Arno Rauschenbeutel[1] — [1]Department of Physics, Humboldt University of Berlin, Berlin, Germany — [2]Institute of Physics, National Academy of Sciences of Ukraine, Kyiv, Ukraine

Room-temperature atomic ensembles for quantum technologies are gaining interest due to their accessibility and reduced experimental complexity. One of the main challenges when working with such ensembles is the Doppler-broadening of the atomic transition frequencies. In this work, we present an approach that mitigates Doppler broadening for the upper transition at telecom wavelength in a three-level ladder scheme in ^{87}Rb. The scheme involves driving the lower transition with a strong pump field at the D2-line wavelength of 780 nm, while a weak counter-propagating field at 1529 nm ($5P_{3/2} \to 4D_{5/2}$) probes the dressed state. We experimentally demonstrate that absorption features with sub-Doppler width and an enhanced optical depth can be achieved for the probe field. Moreover, the experimental spectra agree well with the predictions of our dedicated theory framework. Achieving sub-Doppler absorption lines together with high optical depth at the technologically relevant wavelength regime of the telecom C-band is highly relevant for applications in optical quantum technologies.

Q 28.35 Tue 17:00 Philo 2. OG

Self-organized transport in noisy dynamic network — Frederic Folz[1], •Joshua Rainer Ganz[1], Sayan Roy[1], Adish Singha[2], Kurt Mehlhorn[2], and Giovanna Morigi[1] — [1]Theoretische Physik, Universität des Saarlandes, 66123 Saarbrücken, Germany — [2]Max-Planck-Institut für Informatik, Saarland Informatics Campus, 66123 Saarbrücken, Germany

We present a numerical study of multicommodity transport in a noisy, nonlinear network. The nonlinearity determines the dynamics of the edge capacities, which can be amplified or suppressed depending on the local current flowing across an edge. We consider network self-organization for different activation functions and types of noise.

We identify parameter regimes where noise leads to self-organization into more robust topologies, that are not found by the sole noiseless dynamics. Moreover, the interplay between noise and specific functional behavior of the nonlinearity gives rise to different features, such as (i) continuous or discontinuous responses to the demand strength and (ii) either single or multistable solutions. Our study shows the crucial role of the activation function on noise-assisted phenomena.

Q 29: Poster – Quantum Technologies I

Networks, Repeaters, and QKD; Detectors and Photon Sources; Sensing; Solid State Systems; QuanTour

Time: Tuesday 17:00–19:00 Location: Philo 2. OG

Q 29.1 Tue 17:00 Philo 2. OG

Coupling light from an airplane to a single ion — •Hans Dang[1,2], Sebastian Luff[1,2], Martin Fischer[1], Sheng-Hsuan Huang[1,2], Thomas Dirmeier[1,2], Markus Sondermann[1,2], Christoph Marquardt[1,2], and Gerd Leuchs[1,2] — [1]Max Planck Institute for the Science of Light, Erlangen, Germany — [2]Friedrich-Alexander-Universität Erlangen-Nürnberg (FAU), Erlangen, German

Trapped ions are promising candidates for establishing long-distance quantum networks. Their ability to reliably retain quantum information as quantum memories makes them ideal building blocks to create such networks [1]. However, the operation of a quantum network necessitates the exchange of information stored in quantum memories over long distances. An aerial link between ground stations is thus considered as a means to effectively transfer information. As a first step towards establishing long-distance communication, 935 nm photons originating from either a laser or a whispering gallery mode resonator on an airplane have been successfully coupled to a single $^{174}Yb^+$ ion trapped in a parabolic mirror on the ground. Adaptive optics and fibers are used to collect and guide light from the airplane to the ion. The parabolic mirror then focuses the infrared light onto the ion from nearly full solid angle, increasing the efficiency of coupling photons to the ion [2]. This flight experiment is part of the larger German QuNET initiative and aims to develop the technology needed to interface light from a moving source with a single trapped ion.

[1] N. Sangouard et al., Rev. Mod. Phys. 83, 33 (2011)
[2] L. Alber et al., J. Eur. Opt. Soc.-Rapid Publ. 13, 14 (2017)

Q 29.2 Tue 17:00 Philo 2. OG

Towards Quantum Frequency Conversion of Single Photons from Germanium-Vacancy Centers in Diamond — •Jannis Sode, David Lindler, Marlon Schäfer, Tobias Bauer, Felix Rohe, and Christoph Becher — Universität des Saarlandes, Fachrichtung Physik, Campus E2 6, 66123 Saarbrücken

The germanium-vacancy (GeV) center in diamond is a promising candidate for a quantum memory in quantum communication networks due to its large Debye-Waller factor of up to 0.7 and long spin coherence times of more than 20 ms [1]. To facilitate the distribution of entanglement via preexisting optical fiber infrastructure, it is necessary to convert the single photons emitted by the GeV center from the visible spectrum into the low-loss telecom bands.

Here, we present our work towards low-noise, two-stage quantum frequency conversion of single photons resonant to germanium vacancy centers in diamond. The conversion scheme utilizes difference frequency generation in periodically poled lithium niobate waveguides to convert 602 nm photons to 867 nm, followed by a subsequent conversion to 1550 nm. Such a two-stage conversion scheme has been shown to achieve low conversion-induced noise for the conversion of silicon-vacancy centers [2]. We show first results on the conversion efficiency, as well as spectral noise distribution.

[1] K. Senkalla et al. Phys. Rev. Lett. 132, 026901, 2024
[2] M. Schäfer et al. Adv Quantum Technol. 2025, 8, 2300228

Q 29.3 Tue 17:00 Philo 2. OG

Coherent Photon Number State Superpositions in Frequency Converted Photons from SnV Color Centers — •Tobias Bauer, Dennis Herrmann, Marlon Schäfer, David Lindler, Robert Morsch, and Christoph Becher — Universität des Saarlandes, FR Physik, Campus E2.6, 66123 Saarbrücken

Photon-number coherence (PNC) represents both a powerful resource and a potential security concern for optical quantum technologies: it enables encoding and manipulation of information in the photon-number degree of freedom [1], while deviations from ideal one-photon states can compromise the security of quantum communication protocols [2]. Recent advances with semiconductor quantum dots have shown that coherent driving can generate photon-number superpositions on demand with high purity [3], providing deterministic access to vacuum-one-photon states and opening new possibilities for advanced quantum information processing.

We extend these concepts to color centers in diamond by generating coherent photon-number state superpositions from a SnV-center using resonant excitation with varying pulse powers. We further demonstrate that these states are preserved after frequency conversion of the SnV-resonant photons to the telecom C band.

[1] Polacchi, B., Hoch, F., Rodari, G. et al., npj Nanophoton. 1, 45 (2024). [2] Karli, Y., Vajner, D.A., Kappe, F. et al., npj Quantum Inf 10, 17 (2024). [3] Loredo, J.C., Antón, C., Reznychenko, B. et al., Nat. Photonics 13, 803*808 (2019).

Q 29.4 Tue 17:00 Philo 2. OG

Polarization-entanglement distribution over a 28 km urban fiber link at telecom wavelength — •Akriti Raj[1], Tobias Bauer[1], Christian Haen[1], David Lindler[1], Quankui Yang[2], Thorsten Passow[2], Marko Härtelt[2], Jürgen Eschner[1], and Christoph Becher[1] — [1]Universität des Saarlandes, FR Physik, Campus E2.6, 66123 Saarbrücken — [2]Fraunhofer-Institut für Angewandte Festkörperphysik IAF, Tullastr. 72, 79108 Freiburg

Entangled photon pair sources are essential resources for quantum technological applications. AlGaAs Bragg reflection waveguides are promising platform for such sources due to their high nonlinear coefficient, room temperature operation, and non-birefringent nature [1]. By using a type-II SPDC process, the down-converted photons are orthogonally polarized, and the generated photon pairs are inherently polarization entangled. Here, we present the generation and distribution of polarization-entangled photons over a 28 km dark fiber link [2]. The link consists of commercial fiber, deployed both underground and overhead, includes several patching points, resulting in a transmission loss of $\approx$ 19 dB. The source produces a state with 95.7 % fidelity and 92.4 % purity w.r.t. the $|\psi^+\rangle$ Bell state. After transmission over the actively stabilized [2] fiber link, the fidelity reduces to 87.9 % due to residual uncompensated polarization rotation whereas the purity remains unchanged (92 %). In summary, we demonstrate a room-temperature entangled photon pair source at telecom wavelength, suitable for real world quantum applications.

[1] F. Appas et al., J. Light. Technol. 40 (2022).
[2] S. Kucera et al., npj Quantum Inf. 10, 88 (2024).

Q 29.5 Tue 17:00 Philo 2. OG

Narrow-band bi-chromatic photon-pair source for quantum repeaters — •Henning Mollenhauer[1,2], Alexander Erl[1], Morten Kallevik Straume[1,2], Leon Messner[2], Helen M. Chrzanowski[3], and Janik Wolters[1,2] — [1]DLR, Institute of Space Research, Berlin — [2]TUB, Institute of Physics and Astronomy, Berlin — [3]HUB, Department of Physics, Berlin

Distribution of singe photons and their storage in quantum memories are essential building blocks for quantum networks. Many previous implementations of single photon creation, photon distribution, and storage in quantum memories relied on frequency conversion and/or the need for cryogenic environments. Here we report on a photon-pair source, tunable to a quantum memory, compatible with telecommunication wavelengths, and operating at room temperature. The source utilizes spontaneous parametric down-conversion for emission of photon pairs at cesium D1 and telecom C-band wavelengths. A monolithic resonator [1] funnels photon emission into spatially and spectrally well-defined, narrow-band modes with a bandwidth 23 MHz. We present performance metrics of the source and our progress on achieving single-photon storage in a quantum memory. Expanding source and memory to realize entangled state storage will determine the system*s performance for future quantum repeater schemes. [1] Mottola et al. (2020)

Q 29.6 Tue 17:00 Philo 2. OG

Towards storage of c-band heralded photons in a room temperature quantum memory — •Morten Kallevik Straume[1,2], Alexander Erl[1,2], Henning Mollenhauer[1,2], and Janik Wolters[1,2] — [1]DLR, Institute of Space Research, Berlin — [2]TUB, Institute of Physics and Astronomy, Berlin

One of the limiting factors of current global quantum networks is the lack of efficient light-matter interfaces required for quantum repeaters. In recent years, considerable progress has been made in the development of room-temperature quantum memories and compatible narrow-band single-photon sources based on spontaneous parametric down-conversion (SPDC) [1]. Room-temperature quantum repeater platforms are particularly attractive because they avoid the need for cryogenic cooling, operate with significantly lower power consumption, and offer the most favorable scaling potential compared with other state-of-the-art approaches. Here we present our efforts to interface an optical quantum memory [2], utilizing a Λ-scheme implemented in the Cs D_1-line, with a matching telecom -c-band heralded bichromatic photon-pair source.

[1] R. Mottola et al. Opt. Express 28, 3159-3170 (2020) [2] L. Esguerra et. al. PRA 107, 042607 (2023)

Q 29.7 Tue 17:00 Philo 2. OG

Towards consumer-level quantum-secure cryptography using entanglement-based short-range quantum-key-distribution — •Marco Arnds, Luca Graf, Vincent Reissmann, and Ralf Riedinger — Institute for Quantum Physics, Hamburg, Germany

Quantum key distribution (QKD), which generates a cryptographic key via a quantum channel, has paved the way for physically secure communication. Over the last decades, most efforts in developing QKD focused on long-distance implementations, which are costly and challenging due to exponential losses of photons in quantum channels. An alternative approach is hybrid cryptography, where key distribution occurs over short distances, followed by quantum-secure classical encryption over long distances. Initially, an information-theoretically secure Root-of-Trust is exchanged via a quantum channel, which is stored on two end modules. Afterwards, this Root-of-Trust can be employed to generate encryption keys through a classical rekeying algorithm. In this approach, it is possible to spatially separate the end modules and communicate over existing classical infrastructure, since no quantum channel is required after initialisation. We present a compact source for entangled photon pairs that enables short-range QKD. In future work, we aim to implement low-cost end modules based on semiconductor electronics for the detection scheme of the experimental setup.

Q 29.8 Tue 17:00 Philo 2. OG

Towards telecom-to-visible fiber-integrated quantum frequency conversion — •Felix Rohe, Marlon Schäfer, Tobias Bauer, David Lindler, Jannis Sode, and Christoph Becher — Universität des Saarlandes, Fachrichtung Physik, Campus E2.6, 66123 Saarbrücken

Telecom quantum light sources such as quantum dots, as well as weak coherent laser pulses have recently been gaining importance for quantum repeater applications, by entangling the photons with quantum memory nodes, possessing long spin coherence times [1]. However, since most of the quantum memories exhibit an optical interface in the visible or near-infrared, telecom-to-visible quantum frequency conversion is crucial for long-distance quantum entanglement distribution. Here, we present a two-stage conversion scheme to tune single telecom photons to resonance with the tin-vacancy (SnV) center in diamond in a fiber-integrated design using a solid-core photonic crystal fiber (PCF) coupled to a periodically-poled lithium niobate (PPLN) waveguide. The signal photons at 1550 nm are converted to 619 nm in a two-step sum-frequency generation process using a strong pump field at 2062 nm. This fiber-integrated design offers increased robustness against fluctuations of ambient conditions, paving the way for operation outside of a controlled lab environment. We show first results on coupling and conversion efficiencies, as well as noise rates.

[1] Knaut, C.M. et al., Nature 629, 573-578

Q 29.9 Tue 17:00 Philo 2. OG

Towards low noise and high efficient quantum frequency converters in TFLN — •Jonas Babai-Hemati, Ernst-Lukas Kuhlmann, Silia Babel, Laura Bollmers, Laura Padberg, Harald Herrmann, and Christine Silberhorn — Paderborn University, Integrated Quantum Optics, Institute for Photonic Quantum Systems (PhoQS), Warburger Str. 100, 33098 Paderborn, Germany

Quantum memories, such as tin-vacancy centers in diamond, play an essential role in realizing quantum protocols. To link the wavelengths of these memories to the telecom wavelength, compatible quantum frequency converters (QFCs) with high efficiency and low noise are needed. The thin-film lithium niobate (TFLN) platform exhibits outstanding potential in supporting such processes highly confined in waveguides. However, current TFLN structures still suffer from fabrication inhomogeneities, which decrease efficiency and spectrally broaden frequency conversion processes. A spectral broadening of unwanted noise processes can cause a spectral overlap of noise with a wanted process. We simulate a single-stage difference-frequency generation (DFG) in TFLN. This process converts tin-vacancy emission at 619 nm, pumped at 1030 nm, to the telecom C-band (1550 nm). We simulate the efficiency decrease from fabrication tolerances in critical parameters such as the periodic poling structure and waveguide geometry. We also investigate the spectral broadening of noise processes to identify which parameters most strongly contribute to noise in the simulated single-stage DFG System.

Q 29.10 Tue 17:00 Philo 2. OG

Integrated Photonic Chips for Quantum Network Applications — •Tim Engling[1,2], Jonas C. J. Zatsch[1,2], Jeldrik Huster[1,2], Louis L. Hohmann[1,2], Shreya Kumar[1,2], and Stefanie Barz[1,2] — [1]Institute for Functional Matter and Quantum Technologies, University of Stuttgart, 70569 Stuttgart, Germany — [2]Center for Integrated Quantum Science and Technology (IQST), 70569 Stuttgart

Realizing quantum networks requires generating, manipulating, and measuring photonic qubits at network nodes. Additionally, quantum channels connecting different network nodes and an interface between quantum channel and network node are required.

Integrated photonics based on a silicon-on-insulator offers a versatile and robust platform for networked quantum applications because of efficient qubit state manipulation and photon generation via four-wave mixing. Between nodes low-loss quantum channels can be realized using single-mode fibers.

Here, we present our advances in generating single photons and preparing entangled states directly on a chip. Additionally, we present methods for interfacing qubit states between the node and the channel. With our approach, we can transmit maximally entangled qubits with high fidelity between two integrated photonic chips. This is an important step in implementing quantum network protocols.

Q 29.11 Tue 17:00 Philo 2. OG

Towards entanglement swapping between two WGMRs — •Sheng-Hsuan Huang[1,2], Yen-Ju Chen[1,2], Thomas Dirmeier[1,2], Kaisa Laiho[3], Dmitry Strekalov[1], Gerd Leuchs[1,2], and Christoph Marquardt[2,1] — [1]Chair of Optical Quantum Technologies, Friedrich-Alexander-Universität Erlangen-Nürnberg, Staudtstrasse 7/A3, 91058, Erlangen, Germany — [2]Max Planck Institute for the Science of Light, Staudtstrasse 2, 91058 Erlangen, Germany — [3]German Aerospace Center (DLR e.V.), Institute of Quantum Technologies, Wihelm-Runge-Str. 10, 89081, Ulm, Germany

Entanglement swapping is a key ingredient in building advanced quantum networks. To realize entanglement swapping, two sources capable of generating entanglement and producing indistinguishable quantum states are required. Optical whispering-gallery-mode resonators (WGMRs) have been shown to generate polarization entanglement and to produce indistinguishable photons [1,2]. Together, these features make WGMRs a promising platform for realizing entanglement swapping. In this poster, we will discuss our first results and the progress of entanglement swapping between two WGMRs.

[1] Huang SH., et.al., npj Quantum Information 10 (2024), 85
[2] Huang SH., et.al., APL Photonics 10 (2025), 056111

Q 29.12 Tue 17:00 Philo 2. OG

Towards a multi-qubit register based on the GeV color center in diamond for a quantum repeater node — •Simon Gregor Walliser, Katharina Senkalla, and Fedor Jelezko — Institute for Quantum Optics, Ulm University, Albert-Einstein-Allee 11, 89081 Ulm, Germany

The realization of quantum networks will enable secure end-to-end communication and offers a path to overcoming current limitations of quantum devices in terms of scalability.

In a quantum network, quantum repeaters are used to distribute quantum information over long distances. Quantum repeaters based on color centers in diamond are a promising candidate for quantum network nodes.

Group-IV color centers, such as the germanium-vacancy (GeV) center, exhibit long coherence times at millikelvin temperatures and a high Debye-Waller factor.

Additionally, the use of dynamical decoupling (DD) on the electron spin of the GeV center enables coherent control of surrounding ^{13}C nuclear spins.

In more complex quantum-repeater protocols, a higher number of coherently controllable spins is necessary.

In this work, we present our progress on the detection and coherent control of a weakly coupled ^{13}C nuclear spin in the presence of a strongly coupled ^{13}C nuclear spin by using the XY8 and other DD sequences.

Q 29.13 Tue 17:00 Philo 2. OG

Towards Practical Quantum Networks: Atom-Photon entanglement over a metropolitan fiber link — •Maya Büki[1], Pooja Malik[2], Tobias Frank[1], Marvin Scholz[1], Florian Fertig[2], Gianvito Chiarella[1], Yiru Zhou[2], Emanuele Distante[4], Pau Farrera[1,3], Harald Weinfurter[1,2], and Gerhard Rempe[1] — [1]Max Planck Institute of Quantum Optics, Garching, Germany — [2]Ludwig-Maximilians-University, Munich, Germany — [3]Munich Center for Quantum Science and Technology (MCQST), Munich, Germany — [4]University of Florence, Florence, Italy

Entanglement generation and distribution are key capabilities in order to build scalable quantum networks. While long-distance communication requires photons in the telecommunication band, interfacing with existing quantum infrastructure such as atomic quantum processors demands near-visible photons. Here, we demonstrate robust atom-photon entanglement over a distance of 23 km of fiber within the Munich metropolitan area. A single rubidium atom is entangled with a photon at 780 nm, which is converted to the telecom S-band and, after propagation over the long fiber, back-converted to its original wavelength. By using two tailor-made low-noise quantum frequency converters and mitigating polarization drifts and noise we achieve an end-to-end entanglement fidelity above 85%. This experiment demonstrates the integration of atomic quantum nodes with existing fiber networks and thus lays the foundation for practical long-distance quantum communication and information processing.

Q 29.14 Tue 17:00 Philo 2. OG

Atom-Photon Quantum Gate using an Atomic Clock Qubit — •Leart Zuka[1], Tobias Frank[1], Gianvito Chiarella[1], Pau Farrera[1,2], and Gerhard Rempe[1] — [1]Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Straße 1, 85748 Garching, Germany — [2]Munich Center for Quantum Science and Technology (MCQST), Schellingstr. 4, D-80799 München, Germany

Single atoms coupled to optical cavities provide a powerful platform for photonic quantum information processing. Minimizing the influence of external factors like magnetic field fluctuations is a key goal in this endeavor. In this work, we investigate a novel gate protocol that employs a single Rb^{87} atom prepared in a magnetic-field-insensitive clock qubit and coupled to a high-finesse birefringent Fabry-Perot cavity. The cavity's high birefringence creates two well-separated polarization eigenmodes, enabling polarization-selective reflectivity that depends on the atomic qubit state. This allows us to implement a CPHASE gate between the atomic clock states and our photonic qubits. We present simulations based on input-output theory and master-equation modeling that quantify the conditional reflection amplitudes, gate truth table, and resulting fidelities under realistic experimental imperfections such as finite mode matching, cavity loss channels, and multiphoton contributions. We further report on ongoing experimental progress towards implementing the protocol. Our results indicate that atom-state-dependent phase shifts on the photonic qubit are achievable in the current system, providing a viable path toward a robust, high-fidelity, cavity-assisted atom-photon quantum gate.

Q 29.15 Tue 17:00 Philo 2. OG

Interfacing a rack-mounted narrow-band photon pair-source with a quantum memory — •Leon Messner[1,2], Anne Rohwäder[1,3], Mathilde Kakuschke[1,3], Helen Chrzanowski[4], and Janik Wolters[2,3,1] — [1]Advanced Quantum Light Sources UG, Berlin, Germany — [2]German Aerospace Center (DLR), Institute of Space Research, Berlin, Germany — [3]Technical University Berlin, Institut of Physics and Astronomy, Berlin, Germany — [4]Institute of Physics, Humboldt-Universität zu Berlin, Berlin, Germany

We present initial findings on interfacing a rack-mountable photon-pair source with a ladder-type quantum memory in warm Cesium vapor.

The monolithic cavity source generates heralded single photons with bandwidth and frequency consistent with the used memory transition at the D1 line. Using compact, off-the-shelve components, we achieve 45% heralding efficiency and a rate of approximately 50 kcts/(s mW).

Leveraging the noise-free and high-bandwidth photon storage capabilities of our memory [2], we explore applications for heterogeneous quantum networking and synchronization tasks.

[2] Maaß, B. et al., Phys. Rev. Applied **22**, 044050 (2024)

Q 29.16 Tue 17:00 Philo 2. OG

Improving the response of SNSPDs in high brightness environments — •Paul Vatter[1], Niklas Lamberty[1,2], Timon Schapeler[1,2], and Tim Bartley[1,2] — [1]Department of Physics, Paderborn University, Warburger Str. 100, Paderborn, 33098, Germany — [2]Institute for Photonic Quantum Systems (PhoQS), Paderborn University, Warburger Str. 100, Paderborn, 33098, Germany

Superconducting nanowire single-photon detectors (SNSPDs) offer great value as highly efficient single-photon counters and possess a high signal-to-noise ratio even in low-light environments. We investigate possible improvements in the optical response of SNSPDs by varying their efficiency. A lookup table was created, mapping the count rate of an SNSPD to the incoming light intensity and its efficiency, enabling the calculations of signal-to-noise ratios. This data set reveals how the count rate of SNSPDs transitions into plateau and saturation regions at high incoming light intensity. By characterizing the signal-to-noise ratio behaviour across different operating regimes, we quantify how SNSPDs perform at high incoming light intensity when reducing their detection efficiency. These results pave the way for deploying SNSPDs in a broader range of applications, including those involving high brightness environments.

Q 29.17 Tue 17:00 Philo 2. OG

Electric Field Control of Optical Properties of Carbon Based Quantum Emitters in Hexagonal Boron Nitride — •Niklas Pichel, Mohammad Nasimuzzaman Mishuk, Julien Chénedé, and Tobias Vogl — Department of Computer Engineering, School of Computation, Information and Technology, Technical University of Munich, 80333 Munich, Germany

Color centers in two-dimensional hexagonal boron nitride (hBN) are a compelling platform for realizing stable single photon sources at room temperature. The possibility for on-chip integration of these quantum emitters into e.g. waveguides/photonic integrated circuits is especially appealing for realizing compact and scalable photonic quantum technologies. For these applications, the precise control of the spectral and polarization properties of the photons generated from these color centers plays a crucial role to achieve optimal performance of quantum communication systems or to generate indistinguishable photons required for quantum computing. In this work, we investigate the tunability of the emission wavelength and polarization axis as well as spectral linewidth of single photons emitted from quantum emitters in hBN by applying an external electric field in arbitrary directions. We furthermore perform time-dependent measurements to reveal how the polarization dynamics change under the influence of an applied electric field.

Q 29.18 Tue 17:00 Philo 2. OG

Electrical modelling of superconducting nanowire single photon detectors and challenges for detecting single photons — •Thushara Suraweera Arachchilage[1], Philipp Karl[1], Sandra Mennle[1], Michael Zimmer[2], and Harald Giessen[1] — [1]4th Physics Institute, Research Center SCoPE, and IQST, University of Stuttgart, Pfaffenwaldring 57, 70569 Stuttgart, Germany — [2]IHFG, University of Stuttgart, Allmandring 3, 70569 Stuttgart, Germany

Applications of superconducting devices have become a rapidly evolving research field, and superconducting nanowire single photon detectors (SNSPDs) play a key role in this area. Although some studies have reported improved signal-to-noise ratios (SNR), reproducing these published results has proven difficult. Analyzing these detectors using equivalent electrical-circuit models lead to improvements, and could be deployed for single-photon detection with high accuracy.

This study primarily focuses on the electrical behavior of SNSPDs. As an initial step, contact resistances were investigated, since these contribute significantly to the total impedance of a detector. The obtained contact resistances ranged from tens of ohms to a few hundred ohms, which can pose a major problem for impedance matching with measurement instruments when detecting faint signals.

These observations also highlight the need to study additional variables, such as substrate selection, contact-pad materials, and their oxidation properties, that may influence the SNR of SNSPDs. Identifying these critical problems is the first step toward solving them, and thus enables an improvement in existing SNSPDs.

Q 29.19 Tue 17:00 Philo 2. OG

Single-Shot Fingerprinting of Solid-State Quantum Emitters

— •Sonya Kukulina, Julien Chénedé, and Tobias Vogl — Department of Computer Engineering, School of Computation, Information and Technology, Technical University of Munich, 80333 Munich, Germany

Single-photon emitters in hexagonal boron nitride are promising building blocks for scalable quantum technologies, particularly quantum communication, due to their room-temperature stability, bright emission, and compatibility with nanophotonic integration. Realizing robust, integrated quantum devices requires a clear understanding and consistent classification of these defect centers, motivating the development of an efficient, integrated characterization framework.

This work presents an optical measurement platform designed for single-shot fingerprinting of individual quantum emitters. The system integrates confocal scanning photoluminescence imaging, fluorescence lifetime mapping, second-order correlation measurements, spectral analysis, and polarization control over both excitation and emission within a unified, software-automated architecture. Dual excitation channels provide through-objective and side-fiber excitation, while three detection outputs in reflection, transmission, and side channels provide comprehensive readout of optical characteristics. This parallel acquisition scheme enables simultaneous mapping of multiple emitter properties within a single apparatus, supporting systematic identification and yielding consistent benchmarking for the development of solid-state quantum communication systems.

Q 29.20 Tue 17:00 Philo 2. OG

Optimising time multiplexed multi-loop heralded single photon sources — •Zora Kutz[1,2,3], Xavier Barcons Planas[1,2,3], Lasse Wendland[1], Jasmin Meinecke[1], and Janik Wolters[1,2,3] — [1]Technische Universität Berlin — [2]Deutsches Zentrum für Luft und Raumfahrt — [3]Physikalisch-Technische Bundesanstalt

To achieve quasi-deterministic heralded single-photon sources, the probabilistic nature of spontaneous parametric down conversion can be mitigated with time-multiplexing. At the event of a photon-pair generation, the signal photon is stored in a switchable fibre delay line of single [1] or multiple loops [2] until release. Photons can be spaced at regular intervals for later use in computing applications. Implementing storage loops of different lengths reduces the amount of necessary round trips and thus also overall losses. A setup applicable for single or multi-loop usage was realised. For further optimisation, the effect of tip/tilt degree of freedom of a collimator lens on a single mode gaussian beam was investigated in its regard to mode matching.

[1] T. B. Pittman, B. C. Jacobs, und J. D. Franson,Phys. Rev. A, Bd. 66, Nr. 4, S. 042303, Okt. 2002

[2] E. Lee, S. M. Lee, und H. S. Park, Opt. Express, Bd. 27, Nr. 17, S. 24545, Aug. 20192

Q 29.21 Tue 17:00 Philo 2. OG

Characterization of the swelling behavior of hydrogels using a laser-written Mach-Zehnder interferometer — •Johannes Schnegas[1], Karoline Becker[2], Alexander Szameit[2], and Udo Kragl[1,3] — [1]Institute of Chemistry, University of Rostock, Germany — [2]Institute of Physics, University of Rostock, Germany — [3]Department Life, Light & Matter, Faculty for Interdisciplinary Research, University of Rostock, Germany

Hydrogels are 3D polymer networks that can absorb water depending on the surrounding media, such as salt concentration or pH. This allows the use of hydrogels as sensor materials. Swelling directly affects the refractive index of the hydrogel. An integrated optical interferometer, such as the Mach-Zehnder interferometer, is an appropriate sensor for investigating swelling-induced refractive index changes. Its chemical sensing capability has been demonstrated in the literature. In this study, a fs-laser-written MZI fabricated in fused silica was used, which is composed of two waveguides combined by evanescent field couplers. One part of each interferometer arm runs close to the glass surface. A sensor area was created by exposing one of these via mechanical polishing, whereas the other interferometer arm served as a reference. A liquid sample applied to the sensor area results in a shifted phase to which the interferometer responds with a change in the output intensity. This study examines the capability of a laser-written Mach-Zehnder interferometer to characterise the swelling behaviour of hydrogels in different surrounding media.

Q 29.22 Tue 17:00 Philo 2. OG

Fiber fluorescence spectra and their impact on NV-based sensors — •Stefan Johansson, Alexander Bukschat, Jonas Gutsche, Dennis Lönard, Alena Erlenbach, and Artur Widera — RPTU University Kaiserslautern-Landau, Physics Department and State Research Center OPTIMAS, Kaiserslautern, Germany

Optical fibers are widely used as light-guiding components in sensing applications, including quantum sensors based on nitrogen-vacancy (NV) centers in diamond. For such miniaturized, fiber-integrated NV magnetometers, background fluorescence generated within the fiber, arising from scattering processes and intrinsic photoactive impurities, can spectrally overlap with the NV centers' fluorescence. This autofluorescence reduces the signal-to-noise ratio and ultimately limits the achievable magnetic-field sensitivity, particularly when the number of active spins is small. We systematically analyze the optical emission spectra of commonly used optical fibers under excitation at wavelengths relevant for NV centers. We investigate the influence of the materials used in the fabrication process and fiber type, and we study how the generated background light scales with excitation power. Based on these measurements, we identify characteristic spectral features and evaluate which fibers introduce the lowest fluorescence background in the NV centers' detection band.

Our results provide practical guidelines for selecting optimal optical fibers for NV-based quantum sensors and offer insights applicable to a broader field of fiber-coupled fluorescence-based sensors.

Q 29.23 Tue 17:00 Philo 2. OG

Nanoscale Temperature Sensing with Nitrogen-Vacancy Centers in Diamond — •Anja Jovicevic, Wanrong Li, and Oliver Benson — Humboldt-Universität zu Berlin, Germany

Negatively charged nitrogen-vacancy (NV) centers in nanodiamond offer powerful quantum sensing capabilities, particularly for nanoscale thermometry. We exploit the temperature-sensitivity of the ground-state zero-field splitting (ZFS) in NV centers in nanodiamonds: as the diamond lattice expands thermally, the ZFS shifts, and we track the shift using optically detected magnetic resonance (ODMR) under controlled thermal conditions. Excitation is performed with a green laser, while microwave radiation drives the spin transitions; we monitor the resulting fluorescence in the red to near-infrared wavelength regime. We establish a temperature calibration based on the frequency shift of the ODMR resonance. Our measurements for the resonance frequency shift per Kelvin are in agreement with previously reported values of about -77kHz/K. We will introduce gold nanospheres as local heat sources and observe the induced temperature rise in nearby NV centers. This hybrid configuration is intended to form the basis for applications in biological environments: by combining quantum thermometry with localized heating, one could map and control temperature gradients inside living cells with nanometer precision.

Q 29.24 Tue 17:00 Philo 2. OG

Sparse Optimization of Quantum Fourier Transform Spectroscopy — •Chinmay Sangavadekar[1], Zhengjun Wang[1,2], and Frank Schlawin[1,2,3] — [1]University of Hamburg, Luruper Chaussee 149, Hamburg, Germany — [2]Max Planck Institute for the Structure and Dynamics of Matter, Hamburg, Germany — [3]The Hamburg Centre for Ultrafast Imaging, Hamburg, Germany

Nonlinear interferometers are of fundamental importance for quantum-enhanced photonic sensing. They are able to perform measurements in the infrared regime while relying only on the detection of visible photons and their interactions [1]. Here we present a theoretical framework for quantum Fourier transform infrared spectroscopy using a cw source where a full analytic expression for the quantum interferogram based on signal photon count rate is derived and the complex transmittance is extracted via Fourier transformation. We further explore how sparse optimization may reduce the necessary number of measurements and thereby speed up data acquisition.

[1] G. Barreto Lemos, M. Lahiri, S. Ramelow, R. Lapkiewicz, and W. Plick, "Quantum imaging and metrology with undetected photons: tutorial," J. Opt. Soc. Am. B 39, 2200-2228 (2022).

Q 29.25 Tue 17:00 Philo 2. OG

An all-optical magnetic field quantum sensor based on an ensemble of Tin-vacancy color centers in diamond — •Anna Fuchs, Fabian Voltz, and Christoph Becher — Universität des Saarlandes, Saarbrücken 66123, Germany

Quantum sensing promises new opportunities in applied physics and life sciences due to high sensitivity, precision, and high spatial resolution. A possible implementation of a quantum sensor that became well known in recent years is based on NV centers in diamond. Whereas NV center based quantum sensors are based on microwave manipulation

of their spin states, the negatively charged group IV-vacancy centers in diamond offer the option of an all-optical, microwave-free coherent control of their spin states. This allows for applications where the use of microwave fields is detrimental or technically challenging.
We here investigate an ensemble of negatively charged Tin-vacancy (SnV^-) centers for its suitability for quantum sensing. To this end we use an experimental implementation based on coherent population trapping where two spin states are coupled to an excited state via two laser fields. To detect small magnetic changes we fix the laser frequency to the steepest slope of the dark-state resonance and detect the Zeeman shift by a change in the absorption signal. We report first experimental results on characterising our sample for achievable sensitivities.

Q 29.26 Tue 17:00 Philo 2. OG

Design and optimisation of microantenna for quantum sensor — •Anish Thomas, Alena Erlenbach, Stefan Johansson, Dennis Lönard, Jonas Gutsche, and Artur Widera — RPTU University Kaiserslautern Landau

Nitrogen-Vacancy(NV) centers in diamond are defects with spin characteristics that serve as highly sensitive magnetometers. This makes them suitable for quantum sensing applications, such as magnetic imaging of biological specimens and study of other quantities such as electric fields, temperature and pressure. Initializing these spin state of these centers requires a strong, homogenous magnetic field, emitted by a micro antenna structure on the tip of an endoscopic fiber at the microwave near-field range. This study reports on simulations conducted of the antenna structure with different geometries to analyze the magnetic field within the NV diamond volume with varying parameters. With this, one can calculate, map out and optimize measurable Rabi oscillations with appropriate impedance matched conditions.

Q 29.27 Tue 17:00 Philo 2. OG

Hybrid photonic circuits for fundamental quantum physics — •Yigit Erarslan[1], Alessandro Palermo[2], Zoya Polschykova[2], Akhil Gupta[3], Josef Hloušek[1], Gregor Weihs[1], Rachel Grange[2], Robert Chapman[2], Tobias Vogl[3], and Robert Keil[1] — [1]Universität Innsbruck, Innsbruck, Austria — [2]ETH Zurich, Zurich, Switzerland — [3]Technical University of Munich, Munich, Germany.

Quantum mechanics accurately describes microscopic and many mesoscopic phenomena, yet it relies on postulates that must ultimately be tested experimentally.

We are developing an experimental platform to test two such foundations: the Born rule and the complex-valued nature of quantum amplitudes. Using single-photon multi-path interferometers, we aim to improve the accuracy of these tests by about one order of magnitude compared to the current state of the art, thereby narrowing the parameter space of generalised quantum theories.

The platform is a hybrid quantum system combining room-temperature single-photon emitters based on hexagonal boron nitride, quantum frequency conversion from visible wavelengths to the telecom C-band, and waveguide interferometers on a single lithium-niobate-on-insulator photonic chip. The contribution will present the experimental concept, the planned hybrid photonic circuit, the required steps for its fabrication and characterisation, as well as the targeted sensitivities for these precision tests.

Q 29.28 Tue 17:00 Philo 2. OG

Quantum Emission in Monolayer WSe2 Transferred onto InP Nanowire Waveguides — •Jasleen Kaur Jagde[1], Palwinder Singh[1,2], Megha Jain[2,3], Edith Yeung[2,4], David Northeast[2], Simona Moisa[2], Seid Mohammed[2], Jean Lapointe[2], Una Rajnis[1], Annika Keinast[1], Philip Poole[2], Dan Dalacu[2,3,4], and Kimberley Hall[1] — [1]Department of Physics and Atmospheric Science, Dalhousie University, Halifax, Nova Scotia B3H 4R2, Canada — [2]National Research Council Canada, Ottawa, Ontario K1A 0R6, Canada — [3]Centre for Nanophotonics, Department of Physics, Engineering Physics, and Astronomy, Queen's University, Kingston, Ontario, K7L 3N6, Canada — [4]University of Ottawa, Ottawa, Ontario, K1N 6N5, Canada

Two-dimensional materials like Transition Metal Dichalcogenides (TMDs) have shown exceptional promise for on-demand solid state single-photon emitters in which strain enables site-selective, localized quantum emitter formation. It is viable to integrate these within photonic structures such as waveguides using pick-and-place methods. In our study, we demonstrate quantum emission in monolayer WSe2 deposited onto horizontally aligned InP nanowire waveguides (NWs). The faceted nature of NWs renders control in tailoring the strain-induced QE locations relative to the traditional rectangular waveguide geometries by the potential orientation of QEs on the top surface for efficient coupling. Multiple bright and narrow emission peaks are observed in the 715-785 nm spectral range, along with g(2)(0) as low as 0.049, indicative of high purity single photon generation.

Q 29.29 Tue 17:00 Philo 2. OG

Cavity-Enhanced Molecular Qubits Based on Ground-State Triplet Carbene Molecules — •Nico Striegler[1], Simon Roggors[1], Thomas Unden[1], Alon Salhov[1], Oleksiy Khavryuchenko[1], Jochen Scharpf[1], Gregor Bayer[1], Nick Lester Jobbit[2], David Hunger[2], Martin B. Plenio[1], Alex Retzker[1], Fedor Jelezko[1], Matthias Pfender[1], Philipp Neumann[1], Tim R. Eichhorn[1], and Ilai Schwartz[1] — [1]NVision Imaging Technologies GmbH — [2]Karlsruhe Institute of Technology (KIT)

Molecular qubits have emerged as chemically tunable alternatives to point defects in solid-state systems. In this work, we present a molecular spin photon interface based on ground-state triplet carbene molecules embedded in a molecular matrix. These organic qubits feature two unpaired electrons that allow for optical initialization and readout with a fluorescence contrast exceeding 40%. Using photoactivation, we achieve precise control over qubit density and spatial distribution, resulting in long spin coherence times ($T_2 = 157(4)$ μs at 5 K). To enhance the spin-photon interaction, we integrate molecular crystals containing carbene molecules into optical microcavities and perform low-temperature characterization measurements.

Q 29.30 Tue 17:00 Philo 2. OG

Role of time delay in two-color excitation protocols — •Zahra Noorinejad, Thomas Bracht, Doris Reiter, and Moritz Cygorek — Condensed Matter Theory, Department of Physics, TU Dortmund, Dortmund 44221, Germany

Fast excitation of a quantum dot (QD) on the order ofpicoseconds is one of the most important ingredients in quantum optics and quantum photonics. It has been suggested to use two-color excitation to achieve population inversion, for example in Nature Physics, volume 15, 941*946 (2019) by Y. He et al., and in Phys. Rev. Lett. 126, 047403 (2021) by Z. X. Koong et al. We resolve the apparent contradiction between these two papers and attribute it to the role of the time delay between the pulses. By several examples, we show that by controlling the time delay, one can tune the resonant Rabi oscillation and thereby obtain complete population inversion. Finally, we calculate the effect of phonons on our results.

Q 29.31 Tue 17:00 Philo 2. OG

Laboratory management software: Plesty: Python Library for Experimental Science and Technology — •Maximilian Heller, Frederik Benthin, Christopher Borchers, Nico Eggeling, Tom Fandrich, Dolores Garcia de Viedma, Joscha Hanel, Martin Hesse, Marcel Pölking, Tom Rakow, Pavel Sterin, Fei Ding, Jens Hübner, and Michael Zopf — Leibniz Universität Hannover, Institut für Festkörperphysik, Appelstraße 2, 30167 Hannover

Optical measurements often involve complex protocols requiring the coordination of many different devices. Laboratory management software such as DynExp, MAHOS, NOMAD-CAMELS and Qudi assist in performing these tasks and can *inter alia* provide a unique framework for configuration and concertation of a fully equipped laboratory via, e.g., standalone graphical user interfaces (GUI) for device control.

Here we present Python Library for Experimental Science and Technology (Plesty), which is a highly modular, standards based Python framework for advanced laboratory control. Among the main design goals are automatic metadata recording, distributed device coordination, modular and flexible but standardized code organization as well as independent and common GUIs. Analyzer GUIs perform common analyses specific to, e.g. photoluminescence spectroscopy and time-correlated single-photon counting of quantum dot single-photon sources.

Q 29.32 Tue 17:00 Philo 2. OG

Characteristics of hBN emitters in different conditions — •Raphael Neubacher, Adam Lafferty, Helmut Hörner, Malaika Waheed, Ambika Shorny, Fritz Steiner, Alex Götz, Adarsh Prasad, Stefan Walser, and Sarah M. Skoff — Atominstitut, TU Wien, Stadionallee 2, 1020 Vienna, Austria

Many quantum technologies rely on the development of stable single photon emitters that work under ambient conditions. Hexagonal Boron Nitride (hBN) is a 2D wide bandgap semiconductor which hosts various atomic scale defects that act as optically active centres. Some of these defect states result in bright, stable and spectrally distinct emission of single photons under ambient conditions. The type of the obtained defects is influenced by several factors, such as manufacturing technique, annealing in different gases or suspension in different liquids. Here, we investigate the characteristics of different hBN emitters in different sample types and under different conditions and aim to narrow down the origin of the most common defect types that emit single photons in the visible range.

Q 29.33 Tue 17:00 Philo 2. OG

Coupling single molecules to high-frequency acoustic vibrations — •Mojtaba Aghakasiri[1], Mohammad Musavinezhad[1], Jan Renger[1], Tobias Utikal[1], Felix Mayor[2], Sultan Malik[2], Kaveh Pezeshki[2], Amir Safavi-Naeini[2], Vahid Sandoghdar[1], and Alexey Shkarin[1] — [1]Max Planck Institute for the Science of Light, Erlangen, Germany — [2]Department of Applied Physics, Stanford University, Stanford, USA

Single organic dye molecules are promising building block for solid-state photonic quantum technologies. At cryogenic temperatures they demonstrate strong light-matter interaction, negligible dephasing, and high spectral stability. However, they confront the challenge of nanosecond-scale coherence time limited by the optical excited state lifetime. One way to circumvent this restriction, is to couple molecules to localized acoustic modes in their environment, which could be engineered to have millisecond-scale lifetime.

Here we report on such a hybrid nanophotonic-nanomechanical platform that combines wavelength-scale acoustic waveguides with printed organic host nanocrystals containing single quantum emitters. By exciting guided acoustic modes, we induce a controlled strain field that drives the localized acoustic modes of the nanocrystal and dynamically modulates the molecular resonance frequency. This platform allows for systematic exploration of geometry-dependent coupling strength and mechanical mode lifetime, establishing a route towards engineering systems combining optical access of single quantum emitters and high coherence and versatility of mechanical systems.

Q 29.34 Tue 17:00 Philo 2. OG

Long optical and spin coherence of europium-based organic molecular qubits for quantum information applications — •Preethika Thiraviam[1], Vishnu Unni C.[1], Evgenij Vasilenko[1], Nicholas Jobbitt[1], Barbora Brachnakova[1], Senthil Kuppusamy[1], Timo Neumann[2], Mario Ruben[1], Michael Seitz[2], and David Hunger[1] — [1]Karlsruher Institut für Technologie, Karlsruhe, Germany — [2]University of Tübingen, Tübingen, Germany

Rare-earth doped solid-state materials offer long spin coherence and high-resolution optical transitions, positioning them as building blocks for scalable quantum technologies. Recent success in cavity integration highlights the growing viability in this approach [1]. Building on the results of [2], we investigate different molecular complexes to optimize optical and spin properties toward realizing an optically addressable spin qubit [3]. The increased branching ratio observed in our characterized complexes provide design guidelines for ligand-field engineering. Moreover, we demonstrate ion-ion interactions in both mono- and bi-nuclear complexes, opening a route to deterministic two-qubit quantum gates. Finally, we report first steps toward integrating molecular crystals in a fiber-based microcavity to enhance light-matter interactions [4] aiming to address single ions to implement high fidelity single and two-qubit gates.

[1] Ulanowski et al., PRX Quantum 6, (2025) [2] Serrano et al., Nature, 603, 241-246 (2022) [3] Vasilenko et al., arXiv:2509.01467 (2025) [4] Eichhorn et al., Nanophotonics,14, 1817 (2025)

Q 29.35 Tue 17:00 Philo 2. OG

Theory of Quantum Dot Photon Properties: Influence of Hot States and Phonons — •Jana Schlücking[1], Maximilian Aigner[2], Thomas Bracht[1], Eva Schöll[2], Armando Rastelli[2], and Doris Reiter[1] — [1]TU Dortmund University, 44221 Dortmund, Germany — [2]JKU Linz, Altenberger Straße 69, 4040 Linz, Austria

Semiconductor quantum dots are promising single-photon sources for quantum communication technologies. The generation of indistinguishable photons is essential for these applications, yet it is strongly affected by various decoherence mechanisms. In this work, we investigate how the interaction of a quantum dot and its solid-state environment affects photon indistinguishability as a function of temperature.

We start to model the quantum dot as a two-level system and account for its coupling to a non-Markovian phonon environment. The model is then extendend to include higher excited, so called hot states, which are connected to the excited state through temperature-dependent transitions. At low temperatures, the loss of coherence is mainly caused by pure dephasing processes, while at higher temperatures the decrease of the indistinguishability is dominated by the hot states dynamics.

Our results show excellent agreement between measurement and simulation, which demonstrates that the inclusion of such hot states is crucial to explain the temperature dependence of photon indistinguishability. These insights help to clarify the limitations of often assumed two-level system dynamics and offer guidance for optimizing quantum dots as applicable single photon sources.

Q 29.36 Tue 17:00 Philo 2. OG

Investigation on quantum emitters found in hBN — •Tuna Özdür[1] and Ozan Ari[2] — [1]METU, Ankara, Turkey — [2]Hacettepe University, Ankara Turkey

This work focuses on developing a low-cost, accessible platform to fabricate and characterize bright, room-temperature single-photon emitters (SPEs) in hexagonal boron nitride (hBN) nanoflakes. Using a simple drop-casting method combined with a photoluminescence microscopy, we aim to systematically identify and quantify SPEs suitable for integration into quantum photonic devices.

Q 29.37 Tue 17:00 Philo 2. OG

Deterministic preparation and retrieval of a dark state population in a semiconductor quantum dot for generating time-bin entangled photon states. — •René Schwarz[1], Florian Kappe[1], Yusuf Karli[1,2], Thomas Bracht[3], Saimon Corve da Silva[4], Armando Rastelli[4], Vikas Remesh[1], Doris Reiter[3], and Gregor Weihs[1] — [1]Institute of Experimental Physics, University of Innsbruck, Innsbruck, Austria — [2]Cavendish Laboratory, University of Cambridge, Cambridge, United Kingdom. — [3]Condensed Matter Theory, Department of Physics, TU Dortmund, Dortmund, Germany — [4]Institute of Semiconductor and Solid State Physics, Johannes Kepler University Linz, Linz, Austria

Semiconductor quantum dots are a highly versatile and promising solid-state platform for generating non-classical states of light. While state-of-the-art optical excitation methods target bright excitons or biexcitons, quantum dots can also accommodate optically dark excitons, which cannot be accessed directly via optical excitation methods. Dark exciton states exhibit significantly slower decay rates than their bright counterparts, making them ideal for the deterministic generation of time-bin entangled states [1]. In this work, we perform a full magneto-optical characterization (in-plane magnetic field) of the dark exciton state in a single GaAs/AlGaAs quantum dot emitting at ~800 nm. By combining the magnetic field mixing and chirped laser pulses, we demonstrate the deterministic preparation the dark exciton and a controlled retrieval of its population [2]. [1] Phys. Rev. Lett. 94, 030502 (2005). [2] Sci. Adv. 11.28, eadu4261 (2025)

Q 29.38 Tue 17:00 Philo 2. OG

Tunnelling-assisted excitation of two quantum dots in a nanowire — •Akaash Srikanth[1], Rohan Radhakrishnan[1], Rodion Reznik[3], Gilles Patriarche[2], George Cirlin[3], and Nika Akopian[1] — [1]DTU Electro, Technical University of Denmark, 2800 Kgs. Lyngby, Denmark — [2]C2N, Université Paris-Saclay, CNRS, 91120 Palaiseau, France — [3]St. Petersburg, Russia

Multi-quantum-dot systems provide a robust platform for realizing quantum registers and multi-photon resources such as 2D cluster states. Here, we introduce a tunneling-based excitation scheme in a system of two quantum dots. We first create a spatially indirect exciton delocalized across two dots. Subsequently, electron tunneling converts it into a spatially direct exciton, enabling a localized radiative recombination pathway and hence direct emission. To quantify how inter-dot separation shapes these dynamics, we grow a series of samples comprising two InGaAs quantum dots (growth times 2 s and 5 s) with varying spacings, embedded in AlGaAs nanowires. Finally, we assess whether this platform–scheme combination can outperform established excitation approaches, particularly (a) resonant excitation, which can lead to fluorescence loss, and (b) the SUPER scheme, which typically demands higher excitation powers.

Q 29.39 Tue 17:00 Philo 2. OG

Towards achieving Stirling Cooler operable Single Photon Sources — •Maximilian Aigner[1], Christian Weidinger[1], Eva Schöll[1], Armando Rastelli[1], Jana Schlücking[2], and Doris Reiter[2] — [1]JKU Linz, Austria — [2]TU Dortmund, Germany

For photonic quantum technology applications, a photon indistinguishability close to unity is essential, and even more desirable at elevated temperatures reachable by Stirling cryocoolers. Here, we present temperature-dependent two-photon-interference measurements of the negative trion in a GaAs quantum dot, in excellent agreement with theoretical predictions accounting for electron-phonon interaction and coupling to higher excited (hot) states. We find that the Hong-Ou-Mandel visibility VHOM drops from near unity indistinguishablity with VHOM = 0.966(6) at 4.5 K to VHOM = 0.048(37) at 55 K. We show that this loss can be primarily attributed to the interaction with energetically closely spaced excited trion states. Our results outline pathways toward maintaining high photon indistinguishability at elevated temperatures by employing Purcell enhancement of the emission rate and increasing the energy separation of the excited states.

Q 30: QuanTour III – Spin Physics & Coherence

Inspired by QuanTour, the traveling quantum-dot light source, the sessions QuanTour I-V focus on the physics of quantum light generation in solid-state systems and applications in quantum networks.

Time: Wednesday 14:30–16:30 Location: P 1

Invited Talk Q 30.1 Wed 14:30 P 1
Shedding light on nuclear spins: from collective states to a quantum memory — •Mete Atature — Cavendish Laboratory, University of Cambridge

Optically active spins in solids are strong candidates for scalable devices towards quantum networks. Semiconductor quantum dots set the state-of-the-art as single-photon sources with high level tuneability, brightness, and indistinguishability. In parallel, their inherently mesoscopic nature leads to a unique realisation of a tripartite interface between light as information carrier, an electron spin as a proxy qubit, and an isolated nuclear spin ensemble. The ability to control these constituents and their mutual interactions create opportunities to realize an optically controllable ensemble of ~50,000 spins. The talk will take a journey from treating the quantum dot nuclei as an uncontrolled noise source limiting spin coherence to the observation of their collective magnon modes and eventually to their function as a quantum register, all witnessed via a single electron spin driven by light.

Q 30.2 Wed 15:00 P 1
Spin-photon entanglement for the generation of multiphotonic graph states — •Lara Couronné[1,2], Hêlio Huet[2], Emilio Annoni[1,2], Petr Steindl[2], Aristide Lemaître[2], Martina Morassi[2], Anton Pishchagin[1], Sébastien Boissier[1], Olivier Krebs[2], Samuel Mister[1], Stephen Wein[1], Viviana Villafane[1], Dario Fioretto[1,2], and Pascale Senellart[2] — [1]Quandela, Massy, France — [2]C2N, Palaiseau, France

Measurement-based quantum computing requires large multi-photon entangled states. We generate these resource states using InGaAs quantum dots as high-efficiency single-photon sources. Each dot holds an extra charge carrier whose spin state maps to the polarization of an emitted photon via optical selection rules, enabling the Lindner-Rudolph protocol.

A small transverse magnetic field causes spin precession. Triggering photon emission while the spin is in superposition produces spin-photon entanglement; repeating this cycle yields multi-photon cluster states. This approach has been shown by several groups and recently extended to more complex states.

In this talk, we present our implementation, achieving entanglement of up to 10 photons. The main challenges are limited spin coherence and excited-state precession. To mitigate these, we use dynamical decoupling to extend coherence and time-filtering to remove photons affected by long excited-state precession. These advances mark a key step toward small-scale demonstrations of fault-tolerant photonic quantum computing.

Q 30.3 Wed 15:15 P 1
Modeling coherent Faraday spin control in semiconductor quantum dots — •Jan M. Kaspari[1], Zhe Xian Koong[2], Dorian Gangloff[2], and Doris E. Reiter[1] — [1]TU Dortmund, Dortmund, Germany — [2]University of Cambridge, Cambridge, United Kingdom

Semiconductor quantum dots (QDs) not only offer exceptional optical coherence and efficiency when coupled to photonic structures but also exhibit remarkably long electronic and nuclear spin coherence times, which makes them stand out as promising building blocks for memory-assisted quantum network protocols. However, these schemes require both the ability to encode information via quantum control over the spin and the possibility to perform single-shot readouts. While spin control in QDs is possible by applying an in-plane magnetic field (Voigt configuration), attempts to overcome the limitations given by the lack of intrinsically cyclic transitions to realize simultaneous single-shot readouts have shown limited success. In the presence of a magnetic field oriented along the growth-axis of the quantum dot (Faraday geometry) circularly polarized cyclic transitions allow for efficient single-shot readouts. Here, we show that electron-spin resonance can be driven and quantum control over the spin can be achieved using a narrowband stimulated Raman scheme exploiting the small light-hole admixture. This slightly breaks the full cyclicity and leads to a highly asymmetric Λ system, which our theoretical model reproduces in excellent agreement with experiment [1].

[1] Zhe Xian Koong et al., arXiv:2509.14445 (2025)

Q 30.4 Wed 15:30 P 1
Temporal coherence of interlayer excitons in TMDC heterobilayers — •Ibrahim sarpkaya — Bilkent University - UNAM, Ankara 06800, Turkey

Semiconducting transition metal dichalcogenides (TMDCs) and their van der Waals heterostructures have been extensively studied during the last decade. Due to their long spontaneous emission lifetime, permanent electric dipole moment, and tunable light emission characteristics, interlayer excitons (IXs) of TMDC heterobilayers have great potential to be the primary candidates for the advancement of valleytronic and optoelectronic devices in the future. However, some open questions related to their temporal coherence and the nature of the interaction between the two spin states of them still need to be answered. In this talk, I will first talk about our recent work focusing on the effect of moiré potentials on the temporal coherence properties of IXs [1]. Then, I will discuss the coherent coupling between two spin states of the IXs and demonstrate the quantum beat pattern as a signature of this coupling [2].

[1] Durmuş et al. npj 2D Mater Appl 7 (2023).
[2] Durmuş, M. A. & Sarpkaya, I. Nano Lett. 24 (2024).

Q 30.5 Wed 15:45 P 1
Single photons for quantum position verification — Kirsten Kanneworff, Mio Poortvliet, Petr Steindl, and •Wolfgang Löffler — Leiden Institute of Physics, Leiden, the Netherlands

We show our progress towards experimental demonstration of quantum position verification using demultiplexed photons from a quantum dot - microcavity single photon source. Quantum position verification is a future quantum network application where the geographic location enables remote authentication of a party, without the need that the parties exchange private keys physically. This remote position verification cannot be done classically and might provide a clear quantum advantage - based on combining the speed of light limit of special relativity with the quantum no-cloning principle. We implement a loss-tolerant protocol with photons produced in a semiconductor quantum dot - cavity system that undergo Hong-Ou-Mandel quantum interference at the location to be verified. We show our lab demo experiment, and discuss challenges for future implementations of quantum position verification in quantum networks.

Q 30.6 Wed 16:00 P 1

Fourier-transform limited, blinking-free quantum dots — •Patricia Kallert[1], Lukas Hanschke[1], Eva Schöll[1], Melina Peter[2], Juan Nicolás Claro-Rodríguez[1], Ailton José Garcia Jr.[2], Saimon Filipe Covre da Silva[2], Santanu Manna[2], Armando Rastelli[2], and Klaus D. Jöns[1] — [1]PhoQS Institute, CeOPP, and Department of Physics, Paderborn University, Paderborn, Germany — [2]Institute of Semiconductor and Solid State Physics, Johannes Kepler University Linz, Linz, Austria

Most photonic quantum technologies require a source of highly indistinguishable photons. Achieving Fourier-transform limited photons is considered a pathway to near perfect indistinguishability. Our work highlights the capability of semiconductor quantum dots. Typically charge and spin noise limit the proximity to it, while the preparation of the quantum dot in a charge-stable state is crucial for non-blinking behaviour. [1] The integration of droplet-etched GaAs in AlAs in p-i-n diodes leads to Fourier-transform limited and blinking-free single-photon emission that leads to raw Hong-Ou-Mandel visibilities of (91.7 ± 0.6) % for the negative trion at resonant π excitation.

[1] A. V. Kuhlmann et al. Charge noise and spin noise in a semiconductor quantum device. Nature Physics (2013), pp. 570-575. issn: 1745-2481. doi: 10.1038/nphys2688.

Q 30.7 Wed 16:15 P 1

Floquet-Engineered Two-Photon Excitation of Biexcitons — •Paul C. A. Hagen[1], Jun-Yong Yan[3], Moritz Cygorek[2], Doris E. Reiter[2], Feng Liu[3], and Vollrath M. Axt[1] — [1]TPIII, Universität Bayreuth, Germany — [2]CMT, TU Dortmund, Germany — [3]Zhejiang University, China

Semiconductor quantum dots (QDs) are promising solid-state platforms for generating on-demand single and entangled photons in quantum technology applications. Two-photon excitation (TPE) is a key technique for creating biexcitons, where two degenerate photons are simultaneously absorbed by a QD to excite it into the biexciton state. We show that this process also occurs when both photons are symmetrically detuned so that their combined energy matches the ground-to-biexciton transition. The excitation becomes most efficient when the detuning exceeds the biexciton binding energy, and a short temporal delay between pulses is introduced. We refer to this approach as Floquet engineered two-photon excitation (FTPE)[1]. FTPE offers concrete advantages over conventional TPE: it is more robust against laser power variations, allows efficient laser filtering, and exhibits both theoretically and experimentally higher excitation efficiency, even in the presence of phonons [1]. Using Floquet theory, we explain its dynamics and demonstrate that stroboscopic models provide an accurate description of the underlying mechanism.

[1] J. Y. Yan, P. C. A. Hagen et al. arXiv: 2504.02753

Q 31: Ultracold Matter IV – Bosons, Rydberg Systems, and Others (joint session Q/A)

Time: Wednesday 14:30–16:30 Location: P 2

Q 31.1 Wed 14:30 P 2

Interfacing Rydberg atoms with a high overtone bulk acoustic wave resonator in the GHz regime — •Julia Gamper, Valerie Leu, Cedric Wind, Wolfgang Alt, and Sebastian Hofferberth — Institute of Applied Physics, University of Bonn, Germany

Rydberg atoms have electric dipole-allowed transitions from microwave to optical frequencies, making them ideal for hybrid quantum platforms interfacing optical photons and on-chip devices. We specifically are developing a novel hybrid system, coupling Rydberg microwave transitions to the motion of an electromechanical resonator.

In this talk, we present our first approach towards this goal, combining ultracold atoms trapped with an atom chip and a high-overtone bulk acoustic wave resonator (HBAR). Specifically, we aim to use a superconducting Z-wire trap to position atoms near a 4K sample and with optimal overlap with the HBAR electric field. We present our calculations on Rydberg-oscillator coupling, showing that strong coupling between single Rydberg excitation and single phonon is reachable with current HBARs. Our chip design includes a coplanar waveguide resonator, whose second harmonic is resonant with both the Rydberg atoms and the HBAR, enabling classical driving of both components of the hybrid system. Our first application of this hybrid system is cooling of the oscillator mode well below the 4K environment temperature via engineered dissipation of the coupled Rydberg atoms.

Q 31.2 Wed 14:45 P 2

Spectroscopic signatures of emergent elementary excitations in a kinetically constrained long-range interacting two-dimensional spin system — •Tobias Kaltenmark[1], Chris Nill[1,2], Christian Gross[1], and Igor Lesanovsky[1,3] — [1]Universität Tübingen, Tübingen, Germany — [2]University of Bonn, Bonn, Germany — [3]The University of Nottingham, Nottingham, United Kingdom

Lattice spin models featuring kinetic constraints constitute a paradigmatic setting for the investigation of glassiness and localization phenomena. The intricate dynamical behavior of these systems is a result of the dramatically reduced connectivity between many-body configurations. This truncation of transition pathways often leads to a fragmentation of the Hilbert space, yielding highly collective and therefore often slow dynamics. Moreover, this mechanism supports the formation of characteristic elementary excitations, which we investigate here theoretically in a two-dimensional Rydberg lattice gas. We explore their properties as a function of interaction strength and range, and illustrate how they can be experimentally probed via sideband spectroscopy. Here, we show that the transition rate to certain delocalized superposition states of elementary excitations displays collective many-body enhancement. This work can be found in (Kaltenmark et al., 2025, arXiv:2511.13279).

Q 31.3 Wed 15:00 P 2

Dissipative Optical Nonlinearities in Ultracold Ytterbium — •Tangi Legrand, Xin Wang, Anthea Nitsch, Chris George, Wolfgang Alt, Eduardo Uruñuela, and Sebastian Hofferberth — Institute of Applied Physics, University of Bonn, Germany

Photon-photon interactions at the single-quantum level can be achieved and controlled by strong optical nonlinearities arising from interactions between Rydberg excitations in dense and ultracold atomic ensembles. Two-valence-electron species such as ytterbium offer novel advantages, including narrow-linewidth laser-cooling, optical detection and ionization, and access to long-lived nuclear-spin memory states.

In this talk, we present an experiment that investigates the interactions between a large number of Rydberg polaritons propagating simultaneously through a high-density ^{174}Yb medium. Using a narrow-line magneto-optical trap, we prepare dense clouds at microkelvin temperatures and drive Rydberg transitions via a counter-propagating two-photon scheme. A flat-top excitation beam, together with the long Rayleigh range of the near-UV probe, result in a high optical depth per blockade volume. We then generate and characterize Rydberg polaritons under electromagnetically induced transparency conditions and investigate how ytterbium's atomic structure–such as the absence of hyperfine splitting in bosonic isotopes–modifies dephasing mechanisms, blockade behavior, and collective dynamics. In particular, we detect dissipative nonlinearities through photon-antibunching and assess the coherence of the stored excitation.

Q 31.4 Wed 15:15 P 2

Functional approach to quantum depletion in the thermodynamic limit — •Jin Han[1], Thomas Gasenzer[1,2], and Jan M. Pawlowski[2] — [1]Kirchhoff-Institut für Physik, Universität Heidelberg, Im Neuenheimer Feld 227 — [2]Institut für Theoretische Physik, Universität Heidelberg, Philosophenweg 16

We present a study of repulsive U(1)-bosonic gas with large scattering length. The effective action under consideration respects Galilean invariance and provides proper description for superfluidity and neutral superconductivity at an energy regime far below the mass gap of a solitonic excitation. The resolution of this system requires non-perturbative methods, and we apply the functional renormalisation group, formulated for quantum systems at vanishing temperature and finite chemical potential. In particular, we compute the three-momentum scaling of the atomic density over Bose-Einstein condensate and explain its connection with the Lee-Huang-Yang correction characterizing the two-body Tan's contact. To conclude, we promote the idea of anomalous quantum depletion.

Q 31.5 Wed 15:30 P 2

Tuning the Effective Range via Periodic Driving — •Sejung Yong and Axel Pelster — Department of Physics, RPTU Kaiserslautern-Landau, Germany

Combining Floquet physics with Feshbach resonances leads to dynamically created scattering resonances, which can physically be identified as Floquet bound states [1]. Experimentally these emerging Floquet-Feshbach resonances turned out to be observable via particle loss spectroscopy [2]. Thus, periodic driving allows now an unprecedented level of control for both resonance position and width for the s-wave scattering length. Here we extend the Floquet-Feshbach analysis by systematically taking the lowest energy-dependence of the scattering amplitude into account. With this we find how periodic driving changes the underlying effective range, which may have consequences for nonuniversal effects in ultracold quantum gases [3]. Exemplarily we show that a monochromatic drive of a broad magnetic Feshbach resonance yields a narrow Floquet-Feshbach resonace. [1] C. Dauer, A. Pelster and S. Eggert, Phys. Rev. Lett. 135, 033402 (2025). [2] A. Guthmann, F. Lang, L. M. Klein, S. Barbosa, and A. Widera, Sci. Adv. 11, 10 (2025). [3] N. Kaschewski, A. Pelster, and C.A.R. Sá de Melo, Phys. Rev. Res. 7, 033186 (2025).

Q 31.6 Wed 15:45 P 2

Interplay between topology and disorder in driven honeycomb lattices — •Johannes Arceri[1,2], Alexander Hesse[1,2], Moritz Hornung[1,2], Dizhou Xie[1,2], Christoph Braun[1,2], and Monika Aidelsburger[1,2] — [1]Ludwig-Maximilians-Universität, 80799 München, Germany — [2]Max-Planck-Institut für Quantenoptik, 85748 Garching, Germany

Floquet engineering -periodic modulation of a system's Hamiltonian- has emerged as a powerful tool for the realization of exotic, genuinely out-of-equilibrium quantum systems with no static counterpart. In particular, so-called anomalous Floquet phases display topological edge modes even though bulk bands carry zero Chern number, evading the standard bulk-boundary correspondence.

A defining feature of topological phases of matter is their robustness to spatial disorder. Technique to probe the topological nature of engineered Bloch bands often rely on translational invariance of the underlying lattice, thus failing in the presence of disorder. In the present work, we employ an experimental scheme for real-space detection of edge modes to identify disorder-driven phase transitions between two distinct topological regimes in a periodically driven honeycomb lattice.

Moreover, disordered anomalous Floquet systems are predicted to host a unique topological phase -the anomalous Floquet-Anderson insulator- in which chiral edge modes coexist with Anderson-localized bulk bands. We probe localization in the anomalous Floquet regime by performing quantum walks in modulated lattices, with and without a topological interface.

Q 31.7 Wed 16:00 P 2

An autonomous Thouless Pump — •Julius Bohm[1], James Anglin[1], and Michael Fleischhauer[1,2] — [1]Department of Physics and Research Center OPTIMAS, University of Kaiserslautern-Landau, 67663 Kaiserslautern, Germany — [2]Research Center QC-AI, University of Kaiserslautern-Landau, 67663 Kaiserslautern, Germany

The Thouless pump is a paradigmatic example for a dynamical topological process in non-interacting 1+1-dimensional lattice systems [1]. Cyclic variation of lattice parameters can lead to quantized transport of particles in that lattice protected by a topological invariant. By now theoretical as well as experimental approaches for these pumps rely on direct modulation of the lattice parameters in time. Recent experiments [2] have shown, that replacing the lattice parameter by dynamical quantum degrees of freedom can lead to self-sustained topological pumps. We here present a theoretical model, where a single spin controlling the lattice particles and being subject to a constant magnetic field "drives" the system into a pumping phase without explicit time-dependencies. This pumping phase represents a non-equilibrium topological phase in excited eigenstates of the interacting system. We numerically determine the phase diagram of the system with parameter regions of quantized topological transport in the excited eigenstate and trivial phases without quantized transport. We derive analytic approximations for the corresponding critical parameters and introduce a topological invariant governing the topological transport.

[1] D. J. Thouless, Phys. Rev. B 27, 6083 (1983) [2] D. Dreon, et al., Nature 608, 494-498 (2022)

Q 31.8 Wed 16:15 P 2

Dipole induced phonon topology in one-dimensional Rydberg atom arrays — •Christian Gommeringer — Universität Tübingen

We study the topological properties of phonons in trapped Rydberg atom arrays, which arise from dipole-dipole interactions between the atoms. For various one-dimensional geometries, from zigzag to armchair configurations, we analyze the symmetries of the phononic Hamiltonian which give rise to topologically localized phonon excitations on the system boundaries. Because the phonon-phonon interactions here do not naturally respect chiral symmetry, which is crucial for realizing 1D topological phases, we show how an appropriate, geometry-dependent choice of the dipole moment orientation can restore this symmetry and enable topological characterization. The interplay between two phononic degrees of freedom in the harmonic trap potential, mediated by the dipole-dipole interactions, leads to interesting topological phases with winding numbers between zero and two. The corresponding edge states exhibit strong localization and robustness, making them potentially useful for applications in Rydberg-array-based quantum transport.

As an outlook we aim to explore how the phonon topology influences transport phenomena. Topological states in the electronic degrees of freedom in Rydberg arrays have already been shown to support topologically protected photon pumping. Studying the effect of spin-phonon coupling can provide new control mechanisms in the realm of topological transport.

Q 32: Photonics and Biophotonics II

Time: Wednesday 14:30–16:30 Location: P 3

Q 32.1 Wed 14:30 P 3

Alternative phase-reconstruction algorithms for 3D spot-based beam shapes — •Tim-Dominik Gómez[1], Daniel Flamm[2], and Harald Giessen[1] — [1]4th Physics Institute and Research Center SCoPE, University of Stuttgart, Pfaffenwaldring 57, 70569 Stuttgart, Germany — [2]Trumpf GmbH & Co KG, Ditzingen, Germany

Beams with spatially varying, non-Gaussian profiles are essential across diverse research fields, particularly in applications like imaging and material processing. These can be shaped with the help of diffractive or holographic optical elements, such as spatial light modulators or metasurfaces, which in many cases results in the restriction to phase-only manipulating optical elements. The resulting calculation of an appropriate phase mask for a specific 3D beam-shape often use iterative Fourier transform algorithms (IFTA). For free-space propagation the number of 2D Fast Fourier transforms (FFT) involved scale with the number observed layers and is thus computationally intensive. This is the case even if the desired beam shape consists only of a number of high intensity spots in space, as is often required for material processing applications.

In this work, we present alternative algorithms for the generation of phase masks for such 3D, spot-based beam shapes for Fresnel diffraction with Gaussian spots, as well as when using the first Rayleigh-Sommerfeld solution. These do not require the use of 2D Fast Fourier Transforms and promise faster calculation speeds in cases of spots that are highly distributed in the z-direction.

Q 32.2 Wed 14:45 P 3

Si-Te Ring-Resonator Photodetector for the Telecom Band — •Guillermo Godoy[1,2], Saif Shaikh[1,2], Alessandro Puddu[1,2], Ahmad Echresh[1], Kambiz Jamshidi[2], Shengqiang Zhou[1], and Yonder Berencén[1] — [1]Helmholtz Zentrum Dresden Rossendorf, Dresden, Germany — [2]Dresden University of Technology (TU Dresden), Dresden, Germany

Silicon is a widely used material in photonics, particularly for passive photonic elements, but its indirect bandgap (~1100 nm) limits its use as an active material in the telecom bands. Integration with materials like Ge or InGaAs is typically required for lasers and detectors at telecom wavelengths, increasing fabrication complexity and cost. Tellurium incorporation into Si has recently shown promise for extending silicon's optical response into the near-infrared, covering the telecommunication range (~1260-1625 nm). By introducing deep-level states within the Si bandgap, Si-Te enables absorption of sub-bandgap infrared photons, achieving performance comparable to state-of-the-art heterogeneous devices while maintaining CMOS compatibility and enabling monolithic integration. In this work, we implement Si-Te technology in a microring resonator (MRR) to realize a resonant-enhanced photodetector. This approach is expected to significantly enhance Si-Te sub-bandgap absorption through resonant field amplification, enabling narrowband, spectrally tunable detection in the telecom range. It demonstrates a CMOS-compatible route toward compact infrared photodetectors, paving the way for scalable silicon photonic circuits for optical communication and sensing.

Q 32.3 Wed 15:00 P 3

Vectorial SLM Holography for Flat, Low-Aberration Optical Traps — •Fiona Hellstern, Michael Wischert, Paul Uerlings, Kevin Ng, Tim Jeglortz, Stephan Welte, Ralf Klemt, and Tilman Pfau — 5. Physikalisches Institut and Center for Integrated Quantum Science and Technology IQST, Universität Stuttgart

We present a self-developed framework for holographically generating high uniformity optical traps for ultracold atoms using a spatial light modulator (SLM) placed in the conjugate plane of the experiment. By correcting optical aberrations and producing homogeneous potentials, our framework establishes a reliable platform for quantum-gas experiments that require precise control and uniform trapping potentials. This is especially crucial, as spatial intensity variations shift the local chemical potential and can couple low-energy collective modes, making dynamical measurements unreliable. State-of-the-art hologram algorithms, including Gerchberg-Saxton, are often limited in applications for extended potentials. To overcome these limitations, we built a gradient-descent-based hologram optimization toolbox that directly minimizes intensity inhomogeneities. This approach yields smooth, low-aberration traps and achieves an order-of-magnitude reduction in RMS noise compared to conventional Gerchberg-Saxton holography. A central advantage of our framework is that it naturally goes beyond the assumptions of scalar Fourier optics. At numerical apertures around NA = 0.5, standard paraxial models break down, and accurate trap prediction requires non-paraxial and vectorial propagation models.

Q 32.4 Wed 15:15 P 3

Microscopic lasers as biointegrated sensors — •Marcel Schubert — Humboldt Centre for Nano and Biophotonics, University of Cologne, 50939, Cologne

Microscopic lasers combine the unique advantages of laser light with a small footprint and variable material choice, making them ideal light sources for biointegrated optical sensors. Their intense and narrowband emission also allows optical barcoding to identify large numbers of biological cells. In addition, changes of the spectral positions of the laser modes are used for sensing various physical, chemical, and biological stimuli.

Here, we present different micro- and nanolaser devices, called laser particles, for use as intracellular and biointegrated sensors. Laser particles have a typical size of 1-15 μm and are fabricated from either organic dyes doped into a chemically inert matrix or from inorganic semiconductors. As an example, the contractile properties of heart cells are characterized in detail on the level of individual cells as well as in in vivo experiments in zebrafish embryos. We demonstrate that the high signal intensity and elastic nature of light scattering enable deep-tissue sensing at unprecedented depth and spatio-temporal resolution. By making the matrix of the microlasers mechanically flexible, biological forces can also be measured with high precision. Finally, we will present our progress in developing alternative nanolaser platforms that allow to implement various laser mode shapes, therefore making the laser particles more adaptable to specific biological sensing applications.

Q 32.5 Wed 15:30 P 3

Experimental measurement of the non-Abelian Quantum Geometric Tensor in a multiband photonic lattice — •Martin Guillot[1], Cédric Blanchard[1], Martina Morassi[1], Aristide Lemaître[1], Luc Le Gratiet[1], Abdelmounaim Harouri[1], Isabelle Sagnes[1], Robert-Jan Slager[2], F. Nur Ünal[3], Jacqueline Bloch[1], and Sylvain Ravets[1] — [1]Center for Nanoscience and Nanotechnology, CNRS, Paris-Saclay university, 91120 Palaiseau, France — [2]Department of Physics and Astronomy, University of Manchester, Oxford Road, Manchester M13 9PL, United Kingdom — [3]School of Physics and Astronomy, University of Birmingham, Edgbaston, Birmingham B15 2TT, United Kingdom

Recent discoveries in semi-metallic multi-gap systems featuring band singularities have galvanized enormous interest in particular due to the emergence of non-Abelian braiding properties of band nodes. This previously uncharted set of topological phases necessitates novel approaches to probe them in laboratories, a pursuit that intricately relates to evaluating non-Abelian generalizations of the Abelian quantum geometric tensor (QGT) that characterizes geometric responses.

In this talk, we present the first direct measurement of the non-Abelian QGT. We achieve this by implementing a novel orbital-resolved polarimetry technique to probe the full Bloch Hamiltonian of a six-band two-dimensional (2D) synthetic lattice, which grants direct experimental access to non-Abelian quaternion charges, the Euler curvature, and the non-Abelian quantum metric associated with all bands

Q 32.6 Wed 15:45 P 3

Joule-Thomson Cooling of Light in Photonic Lattices — •Marco Steffen Kirsch[1], Giorgos G. Pyrialakos[2], Tom A. W. Wolterink[1], Alexander Szameit[1], Matthias Heinrich[1], and Demetri N. Christodoulides[2] — [1]University of Rostock, Rostock, Germany — [2]University of Southern California, Los Angeles, USA

We report the experimental observation of an all-optical analogue of the Joule-Thomson expansion in nonlinear multimode photonic lattices. By injecting light through a single-site throttle into a significantly larger waveguide array, we induce a power-dependent redistribution of modal populations. Increasing input power drives a condensation of energy into the fundamental mode, resulting in a measurable reduction of the system's optical temperature. Our results demonstrate a controllable pathway for optical cooling in multimode environments, offering new tools for managing coherence and beam quality in complex nonlinear photonic systems.

Q 32.7 Wed 16:00 P 3

Efficient simulation of tapered photonic structures — •Konrad Tschernig[1,2,3], Swati Bhargava[3], Vinzenz Zimmermann[3], Daniel Cruz-Delgado[3], Janik Wolters[1,2], Sergio Leon-Saval[4], Steven Eikenberry[3], Rodrigo Amezcua-Correa[3], and Miguel A. Bandres[3] — [1]Technical University of Berlin, Berlin, Germany — [2]German Aerospace Center (DLR), Berlin, Germany — [3]University of Central Florida CREOL, Orlando, FL, USA — [4]University of Sydney, Sydney, NSW, Australia

Tapered optical structures play a crucial role in modern photonics, enabling efficient coupling, mode conversion, and multiplexing. Modeling such structures is challenging since, as the region of interest shrinks, there is a significant loss of numerical resolution. We present a novel approach to modeling tapered structures by introducing the taper reference frame, which renders the tapered refractive index profile constant. Working in this frame eliminates the need for recalculating or resizing the refractive index distribution, which reduces computational overhead. Most importantly, our approach maintains high resolution in the region of interest, critical for capturing intricate features of the taper. We validate our method by comparing our simulations with analytical solutions. We applied our model to the analysis of photonic lanterns. Our results demonstrate vastly improved accuracy and computational efficiency compared to existing approaches. The proposed tapered reference frame technique enables major advancements in the design and optimization of optical devices across various applications.

Q 32.8 Wed 16:15 P 3

The Gouy phase of singular beams — •Lyubomir Stoyanov[1,2], Gerhard G. Paulus[3,4], and Alexander Dreischuh[1,2] — [1]Sofia University, Faculty of Physics, Department of Quantum electronics, Sofia, Bulgaria — [2]National Centre of Excellence Mechatronics and Clean Technologies, Sofia, Bulgaria — [3]Institute of Optics and Quantum Electronics, Friedrich Schiller University, Jena, Germany — [4]Helmholtz Institute Jena, Jena, Germany

Ever since the first observation of the second harmonic generation (SHG) of the emission of a ruby laser, the nonlinear optics attracts continuous research interest and is a subject of intensive further development. Part of it, is the singular nonlinear optics, a field in photonics in which the objects of interest are beams/pulses with phase and/or polarization dislocations. Not that obvious, but Bessel-Gaussian beams (beams carrying a finite number of concentric rings surrounding a central peak/ring.) can also be classified as singular beams because of these radial phase jumps of π characteristic for their phase profiles. Here we demonstrate both experimentally and by numerical simulations a strong reshaping of the second harmonics of zeroth- and first-order Bessel-Gaussian beams (BGBs). Detailed interferometric measurements showing flat phase profiles of the broadened central part of the SH beam, and between it and the neighboring rings, will be presented, discussed, and compared with numerical simulations. Numerical simulations for third harmonic generation will also be presented and discussed.

Q 33: Cavity QED, QED, and Spin-Boson Systems I

Time: Wednesday 14:30–16:30 Location: P 4

Q 33.1 Wed 14:30 P 4

Cavity-Induced Electronic Phases and Thermodynamics in Low-Dimensional Systems — •Valerii Kozin, Dmitry Miserev, Even Thingstad, Daniel Loss, and Jelena Klinovaja — Department of Physics, University of Basel, Klingelbergstrasse 82, CH-4056 Basel, Switzerland

We present our recent findings in the field of cavity quantum electrodynamics (QED). The talk consists of three parts. In the first part, we explore double quantum dots coupled to a cavity mode, highlighting cavity-induced quantum phase transitions (both continuous and discontinuous) arising from cavity-mediated and Coulomb interactions, which can produce cat states relevant for quantum computing. In the second part, we discuss a mesoscopic two-dimensional electron gas confined in a double quantum well and coupled to a uniform cavity mode. When the number of electrons participating in virtual intersubband transitions is large, the effective photonic potential develops many minima, each behaving as a nearly harmonic oscillator. The energy offsets of these minima determine their statistical weights, collectively leading to an additive correction to the system's heat capacity. This correction exhibits a Schottky anomaly and a $0.5k_B$ plateau at low temperatures. In the final part, we examine the enhancement of superconductivity in a two-dimensional electron gas coupled to a cavity, where stronger coupling linearly increases the superconducting gap, potentially observable via scanning tunneling microscopy. Together, these results underscore the pivotal role of cavity fields in controlling electronic properties for quantum technologies.

Q 33.2 Wed 14:45 P 4

Collective excitations of dissipative time crystals — •Gage Harmon[1], Giovanna Morigi[1], and Simon Jäger[2] — [1]Saarland University — [2]University of Bonn

We investigate the dynamical response across phase transitions in dissipative time crystals. Using Floquet theory, we characterize the excitation spectra associated with the transition from a normal to a time-crystalline phase. Our analysis reveals two distinct types of dynamical phase transitions, distinguished by the behavior of an order parameter: a continuous (second-order) transition, where the order parameter evolves smoothly; and a discontinuous (first-order) transition, where it changes abruptly. The excitation spectra provide clear signatures of these transitions: the continuous transition is accompanied by the closing of a complex gap, whereas the discontinuous transition exhibits the coexistence of two excitation branches. Focusing on a concrete model*cold atoms strongly coupled to an optical cavity*we demonstrate how these excitations can be experimentally probed by driving the cavity with a longitudinal field. This framework not only clarifies the nature of out-of-equilibrium phases but also opens a route toward experimentally probing the universal properties of time-crystalline order.

Q 33.3 Wed 15:00 P 4

Condensate dynamics in higher bands in a Cavity-BEC system — •Hannah Kleine-Pollmann[1,2] and Ludwig Mathey[1,2,3] — [1]Institut für Quantenphysik, Universität Hamburg, 22761 Hamburg, Germany — [2]Zentrum für Optische Quantentechnologien, Universität Hamburg, 22761 Hamburg, Germany — [3]The Hamburg Centre for Ultrafast Imaging, 22761 Hamburg, Germany

We investigate the behaviour of a Bose-Einstein condensate in higher Bloch bands in a driven-dissipative Cavity-BEC system. The condensate is trapped in a bipartite s-p_x-p_y-lattice, with a tunable energy offset. This enables a controlled population transfer from the s-orbital to the nearly degenerate p_x- and p_y-orbitals. The system forms a chiral ground state of the form $p_x \pm ip_y$ with staggered orbital currents. By increasing the transverse pump strength, we drive the system into the superradiant phase, resulting in a self-organized, symmetry-broken sublattice pattern where the chiral order is directly coupled to the superradiant structure. Using Truncated Wigner simulations and complementary mean-field analysis, we map out the phase diagram. Our results show that higher-band condensates coupled to a cavity provide a promising platform for engineering non-trivial orbital order and topological superfluid phases in quantum optical many-body systems.

Q 33.4 Wed 15:15 P 4

Evidence for Mollow-type lasing from Yb atoms in a high-finesse cavity — •Saran Shaju[1], Dmitriy Sholokhov[1], Ke Li[1], Jerome Bach[1], Simon B. Jäger[2], and Jürgen Eschner[1] — [1]Universität des Saarlandes, Experimentalphysik, 66123 Saarbrücken, Germany — [2]Physikalisches Institut, University of Bonn, 53115 Bonn, Germany

We experimentally investigate the characteristics of light exiting a high-finesse cavity as a result of its strong interaction with driven ^{174}Yb atoms. The cavity interacts with the 182 kHz narrow $^1S_0-^3P_1$ inter-combination line, which is also used for pumping, trapping, and cooling of the atoms in a magneto-optical trap (MOT) configuration. The resulting light-matter interface formed by the cold and dense atomic ensemble and the optical cavity is in the strong collective coupling regime of Cavity QED [1]. We observe continuous light emission reminiscent of lasing with a frequency that is shifted from the bare atomic, cavity, and driving frequencies by several orders of the natural linewidth. Furthermore, we observe that this shift is atom number dependent which we attribute to the collectively enhanced light-matter coupling. This phenomenon is investigated through the measurement of cavity output power and the frequency of the emitted light using heterodyne detection. The experimental observations are supported by extensive mean-field simulations that suggest a possible lasing process based on Mollow gain. Our work aims at the understanding and realization of novel light sources that emerge and rely on strong light-matter coupling.

[1] S. Shaju et al., Phys. Rev. A 112, 013705 (2025).

Q 33.5 Wed 15:30 P 4

Cavity-Enhanced Spin-Photon Interface for Single Tin-Vacancy Centers in Diamond — •Andras Lauko[1], Kerim Köster[1], Julia Heupel[2], Philipp Grasshoff[2], Vladislav Bushmakin[3], Michael Kieschnick[4], Michael Förg[5], Thomas Hümmer[5], Cyril Popov[2], Jörg Wrachtrup[3], Jan Meijer[4], and David Hunger[1] — [1]Karlsruher Institut für Technologie — [2]Universität Kassel — [3]Universität Stuttgart — [4]Universität Leipzig — [5]Qlibri GmbH

Building a long-distance quantum network is one of the big challenges in the field of quantum communication, which requires an efficient photonic interface for coherent spins.

Tin-vacancy centers in diamond are a rising candidate among color centers in diamond, enabling higher operating temperatures than silicon-vacancy centers and being less prone to charge noise relative to nitrogen-vacancy centers.

In our experiment, we integrate a diamond membrane into an open access fiber-based Fabry-Perot microcavity to attain emission enhancement in a single well-collectable mode. We present our fully tunable, cryogenic cavity platform operating in a table-top dilution cryostat, and we achieve a cavity-length stability up to one picometer rms. The platform also allows for integration of a superconducting DC magnet and microwave antenna for spin manipulation.

We observe coupling between single tin-vacancy centers and a cavity mode through Purcell-enhanced emission, and cavity-enhanced extinction in transmission.

Q 33.6 Wed 15:45 P 4

Frustration effects and self-consistent matter description in the Dicke-Ising model on the sawtooth chain — •Jonas Leibig, Max Hörmann, Anja Langheld, Andreas Schellenberger, and Kai Phillip Schmidt — Department of Physics, Staudtstraße 7, Friedrich-Alexander-Universität Erlangen-Nürnberg, Germany

We investigate how the exact thermodynamic-limit mapping of the Dicke*Ising model to a self-consistent effective matter Hamiltonian applies to the geometrically frustrated sawtooth chain. The mapping, established in Ref. [2], was recently solved with NLCE+DMRG for the unfrustrated chain in our work [1]. Using the same method, we obtain the zero-temperature phase diagram of the sawtooth geometry and identify frustration-induced features absent in the unfrustrated case. In the frustrated Ising limit, an infinitesimal effective transverse field lifts the classical degeneracy and produces a disorder-by-disorder transition, analogous to the transverse-field Ising model [3].

References

[1] J. Leibig, M. Hörmann, A. Langheld, A. Schellenberger, and K. P. Schmidt, "Quantitative NLCE+DMRG approach for 1D Dicke-Ising models via self-consistent matter Hamiltonians', *to be published* (2025).
[2] J. Román-Roche, Á. Gómez-León, F. Luis, and D. Zueco, "Linear response theory for cavity QED materials at arbitrary light–matter coupling strengths", *Physical Review B* **111**, 035156 (2025).
[3] D. J. Priour, M. P. Gelfand, and S. L. Sondhi, "Disorder from disorder in a strongly frustrated transverse-field Ising chain", *Phys. Rev. B* **64**, 134424 (2001).

Q 33.7 Wed 16:00 P 4

An atomic tweezer array strongly coupled to a cavity — •Stephan Roschinski[1,2], Johannes Schabbauer[1,2], Franz von Silva-Tarouca[1,2], Damien Bloch[1,2], and Julian Léonard[1,2] — [1]TU Wien, Atominstitut, Vienna Center for Quantum Science and Technology (VCQ), Stadionallee 2, 1020 Wien, Austria — [2]Institute of Science and Technology Austria (ISTA), Am Campus 1, 3400 Klosterneuburg, Austria

Quantum technologies promise efficient solutions to problems that are classically intractable. Many quantum algorithms rely on entanglement, making the deterministic generation of highly entangled states a central challenge. Although significant progress has been made across various platforms, such as Rydberg-tweezer arrays, interactions in these systems typically remain local. By contrast, truly global-range interactions can be realized by coupling atoms to a photonic mode. Here, we report on the realization of an atomic tweezer array strongly coupled to a fiber-based Fabry-Pérot cavity, achieving a Purcell factor of 160. This platform provides not only strong, cavity-mediated interactions but also precise single-atom control: the position of each atom along the cavity mode determines its coupling strength, and the cavity enables state-dependent readout. In addition, single-qubit rotations are implemented via a Raman scheme. Together, this toolbox opens the door to exploring the efficient creation of many-body entangled states.

Q 33.8 Wed 16:15 P 4

Cavity elimination in cavity-QED: a self-consistent and non-Markovian input-output theory — •Eliott Rambeau and Loic Lanco — Université Paris Cité, Centre de Nanosciences et de Nanotechnologies, 91120 Palaiseau, France

Simplifying composite open quantum systems, as cavity-QED ones, through model reduction is central to enable their analytical and numerical understanding. In this work, we introduce a self-consistent approach to eliminate the cavtiy degrees of freedom of cavity-QED devices in the non-adiabatic regime, where the cavity memory time is comparable with the timescales of the atom dynamics. We consider a cavity-QED system consisting of a two-level atom coupled to a single-mode cavity, both weakly interacting with the environment through an arbitrary number of ports, within the input-output formalism. We then derive a generalized Purcell formula and, under reasonable approximations, a consistent effective dynamics within a two-dimensional Hilbert space, allowing to simplify both analytical and numerical calculations. The resulting reduced model captures the non-Markovian features of the light-matter interaction, which we characterize through an effective Lindblad equation exhibiting a negative decoherence rate. In the continuous-wave excitation regime, we benchmark our approach by computing effective output flux formulas, correlations and spectral densities, showing an excellent agreement with full CQED simulations, except in the strong coupling high excitation regime. Our results provide a practical framework for reducing the size of a CQED system and could be generalized to more complicated structures.

Q 34: Quantum Technologies – Sensing I

Time: Wednesday 14:30–16:30 Location: P 5

Invited Talk Q 34.1 Wed 14:30 P 5

Spectral Peaked Optical Frequency Comb for Highly Sensitive Cavity Ring-down Spectroscopy — •Hideki Tomita[1], Norihiko Nishizawa[1], Shotaro Kitajima[1], Ryohei Terabayashi[1], Ningwu Liu[1], and Hisashi Abe[2] — [1]Nagoya University, Nagoya, 464-8603, Japan — [2]National Metrology Institute of Japan, AIST, Tsukuba, 305-8563, Japan

Optical frequency combs represent a breakthrough in many research fields. To apply the comb to highly sensitive cavity-enhanced spectroscopy such as cavity ring-down spectroscopy, a specific mode of the comb must be selected and efficiently coupled to a high-finesse optical cavity. We have developed a spectrally peaked optical frequency comb using the novel phenomenon of spectral peaking (N. Nishizawa, et al., Advanced Photonics Research, (2025) https://doi.org/10.1002/adpr.202500022). In this comb, the background pedestal components of the generated spectral peaks can be suppressed. This presentation discusses the principle and fundamental characteristics of the spectral peaked optical frequency comb and shows current progress in its application to cavity ring-down spectroscopy and the future prospects.

Q 34.2 Wed 15:00 P 5

Quantum limits of photon-induced near-field electron microscopy — •Hao Jeng — Department of Ultrafast Dynamics, Max Planck Institute for Multidisciplinary Sciences, Göttingen D-37077, Germany — IV. Physical Institute, University of Göttingen, Göttingen D-37077, Germany

The principles of quantum metrology imply that the sensitivity of current electron microscopes can be improved substantially. An increase in sensitivity would effectively reduce the number of electrons needed, which is crucial for electron microscopes because many specimens are too fragile to survive the constant bombardment by swift electrons. In this contribution, we analyse the fundamental quantum limits for a particular type of electron microscopy known as "photon-induced near-field electron microscopy". We derive bounds on the quantum Fisher information of the system, identify probes that attain these bounds, and find ways to surpass the limits of our instrument using non-classical states of electrons and light.

Q 34.3 Wed 15:15 P 5

Towards the detection of biomagnetic fields using widefield quantum sensing — •Mokessh Kannah Ciwan[1], Baha Sakar[1], Benno Scharpf[1], Evgeniya Kirilina[2], and Nabeel Aslam[1] — [1]Felix-Bloch-Institute for Solid State Physics, University of Lepzig, Leipzig, Germany — [2]Max Planck Institute for Human Cognitive and Brain Sciences, Leipzig, Germany

In this study, we demonstrate the use of nitrogen-vacancy (NV) centers in diamond for widefield magnetometry with a large field of view (FOV, 0.8 x 0.8mm). This substantial FOV enables the simultaneous characterization of multiple NV centers. For sufficient illumination and spin-state manipulation, we utilize a laser with a power output of 2 Watts and a large homemade omega loop structure to deliver microwaves with high powers homogeneously across the entire FOV. Using a CCD camera to recollect the NV fluorescence, we aim to detect biomagnetic fields in the microtesla regime with a spatial resolution of $\sim$1.5 μm.

Q 34.4 Wed 15:30 P 5

Nonlocal cancellation of optical rotations in fructose solutions — wen-chia lo[1,2], •chao-yuan wang[1,2], yu-tung tsai[1,2], sheng-yao huang[1,2], kang-shih liu[1,2], yun-hsuan shih[1,2], ching-

hua tsai[1,2], and chih-sung chuu[1,2] — [1]Department of Physics, National Tsing Hua University, Hsinchu 30013, Taiwan — [2]National Center for Excellence in Quantum Information Science and Engineering, National Tsing Hua University, Hsinchu 30013, Taiwan

Entanglement, one of the most representative phenomena in quantum mechanics, has been widely used for fundamental studies and modern quantum technologies. In this paper, we report the observation of nonlocal cancellation and addition of optical rotations with polarization-entangled photons in fructose solutions. The entanglement also enables probing optical activities at a distance by joint measurements on the entangled photons. The good agreement between the experimental results and theoretical predictions demonstrates the potential for extending these measurements to other chiral molecules, with a sensitivity that improves as the number of entangled photons increases.

Q 34.5 Wed 15:45 P 5

Improving NV Center Magnetometry via Wavelet Enhancement and Memory-Based Protocols — •Matteo Slaviero, Ekrem Taha Güldeste, Justus Tonhäuser, Baha Sakar, and Nabeel Aslam — Felix Bloch Institute for Solid State Physics, Leipzig University, 04103 Leipzig

Wavelet analysis offers a powerful approach to enhance the sensitivity of magnetic field measurements based on nitrogen-vacancy (NV) centers in diamond. In our work, we apply wavelet-based denoising to photoluminescence (PL) traces acquired in optically detected magnetic resonance experiments, where measurement precision is fundamentally limited by photon shot noise. By exploiting the multi-resolution analysis via wavelet decompositions, we selectively suppress noise components while preserving the PL variations that encode the physical quantity of interest. By incorporating appropriate a priori knowledge, wavelet analysis can enable adaptive thresholding to enhance the readout signal. In parallel, we employ sequences that benefit from the increased spin lifetimes of the nuclear spins in the vicinity of the NV. Our results demonstrate a unified approach that combines quantum memory exploitation and wavelet-based enhancement to push the limits of sensitivity and spectral resolution in quantum sensing with NV centers.

Q 34.6 Wed 16:00 P 5

Time-Efficient Nanoscale NMR Using Solid-State Spin Sensors — •Tobias Spohn[1], Nicolas Staudenmaier[1], Philipp J. Vetter[1], Timo Joas[1], Thomas Unden[2], Ilai Schwartz[2], Philipp Neumann[2], Genko Genov[1], and Fedor Jelezko[1] — [1]Institute of Quantum Optics and Center for Integrated Quantum Science and Technology (IQST), Ulm University, Albert-Einstein-Allee 11, 89081 Ulm, Germany — [2]NVision Imaging Technologies GmbH, Ulm D-89081, Germany

Nuclear magnetic resonance (NMR) spectroscopy using solid-state spin sensors offers a powerful platform for detecting nuclear spins at the micro- and nanoscale. While many nanoscale experiments rely on a single sensor spin, employing spin ensembles can substantially enhance sensitivity, particularly when signals arise solely from statistically polarized nuclear spins.

Here, we introduce multipoint correlation spectroscopy, a protocol that integrates the strengths of correlation spectroscopy and quantum heterodyne detection to achieve time-efficient measurements of statistically polarized nuclear spin samples with spin ensembles at the nanoscale. We develop a theoretical framework for this method and demonstrate an experimental proof of concept using a nitrogen-vacancy center in diamond. Our implementation achieves a frequency estimation uncertainty at the single-hertz level, underscoring the potential of this technique for temporally efficient, high-precision nanoscale NMR spectroscopy.

Q 34.7 Wed 16:15 P 5

Understanding the disorder robustness of Over-Un-Twisting echo protocols — •Vineesha Srivastava[1,2] and Klemens Hammerer[1,2] — [1]Institute for Quantum Optics and Quantum Information of the Austrian Academy of Sciences, Innsbruck 6020, Austria — [2]Institute for Theoretical Physics, University of Innsbruck, Innsbruck 6020, Austria

Precision in phase estimation using Ramsey interferometry is limited by quantum projection noise, constraining classical-spin protocols to the standard quantum limit. Entanglement generated through one-axis twisting (OAT) can overcome this limitation, and, in principle, enable sensitivities up to the Heisenberg limit, motivating enhanced Ramsey-echo protocols that apply OAT interactions before and after the phase imprint to surpass simple squeezing schemes.

In earlier work, a variational framework for such echo protocols revealed a previously unknown over-un-twisting (OUT) protocol, in which the initial squeezing is reversed using twice the interaction time. Remarkably, recent experiments on dense room-temperature nitrogen - vacancy ensembles have demonstrated a doubly inverting echo analogous to the OUT protocol, exhibiting disorder-robust signal amplification, which is an effect not fully explained by current theory.

In this work, we investigate the microscopic origins and limits of this robustness. Using cumulant-expansion techniques, we analyze how inhomogeneous spin - spin couplings modify the nonlinear echo dynamics and identify regimes in which OUT-like protocols preserve their metrological advantage.

Q 35: Quantum Computing and Simulation IV

Time: Wednesday 14:30–16:30 Location: P 10

Invited Talk Q 35.1 Wed 14:30 P 10

Quantum field simulation on bosonic platforms — •Tobias Haas — Institut für Theoretische Physik and IQST, Universität Ulm, Albert-Einstein-Allee 11, 89069 Ulm, Germany — Centre for Quantum Information and Communication, École polytechnique de Bruxelles, CP 165, Université libre de Bruxelles, 1050 Brussels, Belgium

Quantum field simulators offer unique opportunities to investigate otherwise inaccessible phenomena through tabletop experiments. Taming the complexity of such inherently high-dimensional models requires efficient encodings paired with experimentally friendly readout methods.

First, we introduce the Optical Time Algorithm (OTA) as a unifying framework that enables the simulation of a wide range of free quantum field dynamics using a single optical circuit design [1]. By modifying the optical elements' parameters, our method allows us to engineer essentially arbitrary timescales, coupling graphs, spacetime metrics, and boundary conditions.

Second, we put forward the classical entropy method as a universal data-driven toolkit for directly probing information measures from typical measurement data [2]. We show that well-known features of quantum information measures carry over to suitably chosen classical measures. As applications, we demonstrate the area-to-volume law transition in the quench dynamics of a spin-1 Bose-Einstein condensate [3,4] and report the first experimental observation of an area law in an interacting quantum field simulator [5].

[1] arXiv:2506.23838 [2] arXiv:2404.12320 [3] PRAL 112, L011303 [4] NJP 27, 043004 [5] arXiv:2510.13783

Q 35.2 Wed 15:00 P 10

Shortcuts to adiabaticity with a quantum control field — •Emma King[1], Giovanna Morigi[1,2], and Raphaël Menu[1,3] — [1]Theoretische Physik, Universität des Saarlandes, D-66123 Saarbrücken, Germany — [2]Center for Quantum Technologies (QuTe), Saarland University, Campus, 66123 Saarbruecken, Germany — [3]CESQ/ISIS (UMR 7006), CNRS and Université de Strasbourg, 67000 Strasbourg, France

Quantum adiabatic dynamics underpins adiabatic quantum computing and quantum annealing. Shortcuts to adiabatic dynamics traditionally use engineered classical drives to suppress non-adiabatic transitions and accelerate protocols. Here we study quantum state transfer in the Landau-Zener model as a minimal setting that captures the essentials of adiabatic evolution, and show that undesired (non-adiabatic) transitions can instead be suppressed by autonomous quantum control. This involves coupling the Landau-Zener qubit to an auxiliary quantum system. By tuning the frequency and interaction strength we modify the joint spectrum and composite quantum dynamics such that the probability of non-adiabatic transitions is reduced by more than two orders of magnitude in favorable regimes. We further identify a practical trade-off: relaxed requirements on the final time precision can be compensated by a longer evolution window. Importantly, the suppression of non-adiabatic transitions also persists in the presence of weak decoherence. Our results provide a clear example where the quantum nature of the control subsystem implements an effective shortcut to adiabaticity without relying on externally engineered classical fields.

Q 35.3 Wed 15:15 P 10

Bosonic QEC: (Squeezed) Cats and Vacua — •Florian Spiess — University of Mainz

Bosonic codes offer a promising route towards resource efficient and scalable quantum error correcting architectures, creating a pathway for fault tolerant quantum computation. An interesting feature and difficulty of some experimentally relevant codes, such as (squeezed) cat-codes, is their approximate nature, meaning they only fulfill the Knill-Laflamme conditions in certain limits of physical parameters.

In this talk we investigate the performance and benefits of squeezed vacuum, fock and cat codes. For the most dominant physical error process in photonic systems, that is photon loss, we analyze how to quantify if such newer encodings, involving squeezing, can help compared to other known bosonic error correcting schemes.

Q 35.4 Wed 15:30 P 10

Enhanced loading of ^{171}Yb in optical tweezer arrays for Quantum Computing — •Clara Schellong[1], Jonas Rauchfuss[1], Till Schacht[1], Ben Michaelis[1], Paul Callsen[1], Tobias Petersen[1], Nejira Pintul[1], Christoph Becker[1,2], and Klaus Sengstock[1,2] — [1]Center of Optical Quantum Technologies University of Hamburg, Luruper Chaussee 149, 22761 Hamburg — [2]Institute for Quantum Physics University of Hamburg, Luruper Chaussee 149, 22761 Hamburg

Neutral atoms in optical tweezer arrays emerge as one of the most promising platforms for quantum computing, simulation, and metrology. In this talk, we present our experimental progress towards a quantum computing and simulation platform using Ytterbium (Yb) as a qubit resource, focusing on the deterministic loading of single atoms. In our experiment, we trap individual ^{171}Yb atoms in an array of tweezers at 759 nm, that is magic not only for the clock states $^1S_0$ and $^3P_0$ but also for the $^3P_1$, m$_F$ =-1/2 state, relevant for cooling and detection. A key step for this platform is the defect-free preparation of these arrays. It is well known that light pulses blue-detuned to the $^1S_0$ - $^3P_1$ transition can induce light-assisted collisions that allow for enhanced loading probabilities of single atoms into tweezers. In our setup, we observe single-atom loading with over 80% efficiency using pulses red-detuned to the cooling transition. We characterize the influence of experimental parameters, like tweezer depth and magnetic field, identifying optimal conditions for frequencies red-detuned to the AC Stark and Zeeman shifted resonance of the F=3/2, m$_F$=-1/2 state.

Q 35.5 Wed 15:45 P 10

Development of a Cryogenic Ytterbium Tweezer Array and Modulation Transfer Spectroscopy of the ^{1}S$_0$ → ^{3}P$_1$ Transition — •Julian Feiler[1,2], Meng Gu[3], Konrad Koenigsmann[3], Jin Yang[3], Max Hachmann[1,2], and Peter Schauss[1,2,3] — [1]Institute for Quantum Physics, University of Hamburg, Hamburg, Germany — [2]The Hamburg Centre for Ultrafast Imaging, Hamburg, Germany — [3]Department of Physics, University of Virginia, Charlottesville, USA

Alkaline-earth-like atoms are a common choice for ultracold neutral atom quantum simulators as well as universal quantum computers. Due to its nuclear spin of 1/2, fermionic ^{171}Yb incorporates a natural two-level system with a very long lifetime, which can be utilized as a qubit.

The objective of the presented experiment is the development of a cryogenic Yb tweezer array for quantum computing. In practice, the assembly of large arrays is limited by the trapping lifetime of the atoms in the optical tweezers. By using a cryogenic shield, collision rates of trapped atoms with background gas atoms can be decreased by several orders of magnitude. Correspondingly, the lifetime of the Yb atoms should increase from minute-scales up to many hours.

We report on the recent progress of the experiment and show data derived from modulation transfer spectroscopy of the ^{1}S$_0$ → ^{3}P$_1$ transition of Yb in a vapor cell. The Zeeman splitting of ^{171}Yb and ^{173}Yb is also studied and shows significant deviations from linear Zeeman effect calculations at intermediate magnetic fields of less than 60 G.

Q 35.6 Wed 16:00 P 10

A neutral atom array in an optical cavity for quantum computing — •Mehmet Öncü[1,2,3], Balázs Dura-Kovács[1,2,3], Jacopo de Santis[1,2,3], Mullai Sampangi[1,2,4], Dimitrios Vasileiadis[1,2,3,4], Adrien Bouscal[1,2,3], and Johannes Zeiher[1,2,3] — [1]Max-Planck-Institut für Quantenoptik, 85748 Garching, Germany — [2]Munich Center for Quantum Science and Technology (MCQST), 80799 München, Germany — [3]Ludwig-Maximilians-Universität, Fakultät für Physik, Schellingstr. 4, 80799 München, Germany — [4]Technische Universität München, Fakultät für Physik, James-Franck-Str. 1, 85748 Garching, Germany

Neutral atoms in optical tweezer arrays have become a leading platform for quantum simulation, metrology, and computation. We leverage these developments to realize a novel experiment that strongly couples a rubidium atom array to a high-finesse optical resonator. We will present our compact and versatile setup, our ability to trap and manipulate individual rubidium atoms in optical tweezers inside the resonator, and the first measurements of their coupling to the cavity mode and coherent excitation to high-lying Rydberg states. This platform enables fast, high-fidelity control and readout, and opens routes toward cyclic error correction with real-time feedback, remote entanglement generation within and between atom arrays, and the quantum simulation of open system dynamics.

Q 35.7 Wed 16:15 P 10

Photonic simulation of quantum field dynamics — •Mauro D'Achille[1], Martin Gärttner[1], and Tobias Haas[2] — [1]FSU Jena — [2]Universität Ulm

Photonic multimode systems are an emerging quantum simulation platform ideally suited for emulating non-equilibrium problems in quantum field theory. I will present a new algorithm to decompose the time evolution operator generated by a large class of field-theoretic quadratic Hamiltonians in terms of optical elements. The peculiarity of this decomposition consists of the way in which the time parameter is taken into account. Indeed, for such a class, it is always possible to decouple the time evolution in time-dependent phase shifters by means of a proper time-independent symplectic transformation, composed by squeezers and beam splitters. I will conclude by presenting physically relevant examples and applications aimed to analyze and simulate how the information measures associated to local and non-local theories spread over time.

Q 36: Matter Wave Interferometry and Metrology I

Time: Wednesday 14:30–16:30 Location: P 11

Q 36.1 Wed 14:30 P 11

Optimal Squeezing in Lossy Bragg Interferometers — •Julian Günther[1,2], Rui Li[2], Jan-Niclas Kirsten-Siemss[2], Naceur Gaaloul[2], and Klemens Hammerer[3] — [1]Institut für Theoretische Physik, Leibniz Universität Hannover, Germany — [2]Institut für Quantenoptik, Leibniz Universität Hannover, Germany — [3]Institute for Theoretical Physics, University of Innsbruck, Austria

Using entanglement for N-particle states in matter wave interferometers allows one to outperform the standard quantum limit of $\frac{1}{\sqrt{N}}$ for the uncertainty in the phase measurement. We consider the use of one-axis twisted, spin squeezed atomic states in light-pulse Bragg interferometers. We evaluate the interferometric phase uncertainty taking into account the fundamental multi-port and multi-path nature of higher-order Bragg processes, and determine optimally squeezed states for a given geometry and pulse shapes. For Gaussian temporal pulses we demonstrate the necessary tradeoff between the squeezing strength and momentum distribution of the incoming atomic state to benefit from the entanglement.

This project was funded within the QuantERA II Programme that has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement No 101017733 with funding organisation DFG (project number 499225223).

Q 36.2 Wed 14:45 P 11

Differential phase estimation and bias correction techniques in cold atom interferometer experiments — •David B. Reinhardt and Matthias Meister — German Aerospace Center (DLR e.V.), Institute of Quantum Technologies, Ulm, Germany

Ellipses are omnipresent in mathematics, computer vision and science. For instance, when analyzing differential interferometric data or performing clock comparisons one often needs to fit an ellipse to a given noisy data set. There are mainly two different approaches to achieve this, the algebraic and the geometric method. However, all fitting methods regardless of the approach typically have different accuracy (bias) vs. precision(variance) trade-offs, and therefore can produce quite different outcomes. In this talk, we present new insights regarding the origin of bias in the differential phase estimation. Further, we show how this knowledge can be used to correct bias in cold atom interferometry experiments and also provide rigorous bounds for the achievable estimation precision. The new findings and methods presented in this talk thus have significant consequences for the understanding and handling of measurement errors of quantum sensors based on differential interferometers.

Q 36.3 Wed 15:00 P 11

Frequency shifts of a transportable Al^+ quantum logic optical clock — •Joost Hinrichs[1,2], Constantin Nauk[1,2], Gayatri Sasidharan[1,2], M. Mazin Amir[1,2], Alexander Bernet[1,2], Pascal Engelhardt[1,2], Sofia Herbers[1], and Piet O. Schmidt[1,2] — [1]Physikalisch-Technische Bundesanstalt, 38116 Braunschweig, Germany — [2]Leibniz University Hannover, 30167 Hannover, Germany

Optical atomic clocks are the most precise measurement tools, achieving fractional frequency uncertainties below 10^{-18}. Transportable systems can exploit this accuracy in a broader range of applications. High-precision frequency ratio measurements on-site at various metrology institutes contribute to fulfill the requirements towards a redefinition of the SI second. Furthermore, transportable optical clocks can be used for relativistic geodesy as they allow height measurements on the cm level over large distances.
Our fully rack-integrated clock setup is based on the ${}^1S_0 \to {}^3P_0$ transition in ${}^{27}Al^+$. A co-trapped ${}^{40}Ca^+$ ion allows for sympathetic cooling and state detection through quantum logic spectroscopy. We present the results of our investigation of various frequency shifts in our optical clock, with a focus on effects related to the linear segmented multilayer Paul trap, like micromotion, heating rates, and ac magnetic fields. Furthermore, we present ground state cooling of an Al^+/Ca^+ two-ion crystal.

Q 36.4 Wed 15:15 P 11

Ultra-low phase noise from X- to the THz-band enabled by Difference Frequency Comb. — •Sebastian Müller, Mikhail Volkov, and Thomas Puppe — Lochhamer Schlag 19, 82166 Graefelfing, Germany

Frequency-comb-based generation of RF and THz signals with record-low phase noise becomes an enabling technology for a variety of applciations from spectroscopy to communication. Here, using an offset-free difference frequency comb, we report ultra-low noise 9.6 GHz microwaves reaching -165 dBc/Hz using optical frequency division (OFD). We also show tunable sub-THz frequency synthesis (0.1-0.5 THz) for characterization of RF components.

Q 36.5 Wed 15:30 P 11

Theoretical optimization of BEC sources for Atom Interferometry — •Claudia Puertas González[1,2], Timothé Estrampes[1,2], Naceur Gaaloul[1], Dana-Codruta Marinica[2], and Eric Charron[2] — [1]Institute of Quantum Optics, Leibniz University Hannover, Welfengarten 1, 30167, Hannover, Germany — [2]Intitute of Molecular Science of Orsay, University Paris-Saclay, 598 Rue André Rivière, 91400, Orsay, France

Bose Einstein condensates (BECs) serve as excellent sources for atom interferometry due to their intrinsic coherence, which can be exploited to test the Universality of Free Fall. The key observable in such experiments is the phase difference between the interferometer arms, that depends on the interrogation time T. The Very Long Baseline Atom Interferometry (VLBAI) experiment, a 10-m high atomic fountain in Hannover, enables interrogation times of several seconds in both single- and dual-species configurations.

Reaching such long T requires a drastic reduction of the BECs expansion, as its natural expansion velocity is too large for precision measurements. In-Trap Lensing (ITL) and Delta-Kick Collimation (DKC) therefore play a crucial role in collimating the condensate prior to interferometry. I present here a theoretical framework for optimizing VLBAI source preparation and illustrate, using numerical simulations, how ITL and DKC enhance collimation and improve overall source quality. Efficient transport from the source to the launch position is equally essential and can be realized through shortcuts to adiabaticity (STA), which suppress excitations and help preserve coherence.

Q 36.6 Wed 15:45 P 11

Vortex N00N states in ring lattices — •Lars Arne Schäfer[1] and Reinhold Walser[2] — [1]Institut für Angewandte Physik, TU Darmstadt — [2]Institut für Angewandte Physik, TU Darmstadt

We study a gas of few bosons in a ring trap that can be superimposed with a light-induced azimuthal lattice potential. Light sculpting permits almost arbitrary control of the potential [1]. We describe a technique that uses time-dependent variations of the lattice to create matter-wave vortex N00N states, where N particles are in an all-or-nothing superposition of two counter-rotating states. To do that, we load the gas adiabatically into the lattice, perform resonant state transfer by Bragg scattering between the interacting many-body eigenstates and release them adiabatically into the free ring. In a Sagnac interferometer, the resulting state can improve measurement precision beyond the standard quantum limit $\Delta\theta_{\mathrm{SQL}}$ to the Heisenberg limit $\Delta\theta_{\mathrm{HL}} = 1/N$.

[1] G. Gauthier, I. Lenton, N. McKay Parry, M. Baker, M. J. Davis, H. Rubinsztein-Dunlop, and T. W. Neely, Direct imaging of a digital-micromirror device for configurable microscopic optical potentials, Optica 3, 1136 (2016).

[2] L. Pezzè, A. Smerzi, M. K. Oberthaler, R. Schmied, and P. Treutlein, Quantum metrology with nonclassical states of atomic ensembles, Rev. Mod. Phys. 90, 035005 (2018).

Q 36.7 Wed 16:00 P 11

Diffraction-phase-free Bragg atom interferometry — •Victor Jose Martinez Lahuerta[1], Jan-Niclas Kirsten-Siemss[1], Klemens Hammerer[2,3,4], and Naceur Gaaloul[1] — [1]Leibniz University Hannover, Institut of Quantum Optics, Welfengarten 1, 30167 Hannover, Germany — [2]Institute for Theoretical Physics, University of Innsbruck, 6020 Innsbruck, Austria — [3]Institute for Quantum Optics and Quantum Information of the Austrian Academy of Sciences, 6020 Innsbruck, Austria — [4]Institute for Theoretical Physics, Leibniz University Hannover, Appelstrasse 2, 30167 Hannover, Germany

Bragg Diffraction of matter waves is an established technique used in the most accurate quantum sensors. It is also the method of choice to operate large-momentum-transfer, high-sensitivity atom interferometers. It suffers, however, from an intrinsic multi-path character. Optimal control theory has recently led to an improved robustness of atom interferometers to a range of challenging environmental effects such as vibrations or platform accelerations. In this theoretical work, we apply OCT protocols to control the Bragg diffraction phase shifts thereby enhancing the metrological accuracy of the interferometer. We show a minimization of the diffraction phase for realistic conditions of finite temperature of the incoming wavepacket in a multi-path, high-order Bragg interferometer in a Mach-Zehnder configuration. We study input states with different momentum widths and find that our approach mitigates diffraction phases below the microradian level in the case of 1% of the photon recoil, thereby eliminating one of the leading systematic effects in atom interferometry.

Q 36.8 Wed 16:15 P 11

'Goos-Hänchen' shifts and tilts in Bragg-Beam splitters with Bose-Einstein condensate — •Abhay Mishra, Adam Abdalla, Oleksandr V. Marchukov, and Reinhold Walser — Institute of Applied Physics, Technical University Darmstadt, Hochschulstr 4a, D-64289, Darmstadt, Germany

The wave optical phenomena of shifts and tilts of finite sized beam interacting with an interface was experimentally proven by F. Goos and H. Hänchen, now collectively known as Goos-Hänchen (GH) effect [1]. This lateral shift of beam was also observed before by Newton [2].

Our work here shows GH shifts in position and momenta of reflected Bose-Einstein condensate (BEC) wavelets emerging from Bragg-beam splitter.These effects become particularly important for precision measurements in long-time atom interferometry, where it can accumulate and result in loss of coherence. Using an analytical picture of superimposing Gaussian wavelets ansatz, we have quantified GH shifts of wavepackets from the expected classical trajectory. It matches with our numerical results of (3+1)D Gross-Pitaeviskii simulations and, significant for QUANTUS collaboration (DLR, grant number 50WM2450E) and broader matter-wave community.

[1] F. Goos and H. Hänchen, Ann. Phys. (Leipzig) 436, 333 (1947).
[2] I. Newton, Opticks, or, A Treatise of the Reflections, Refractions, Inflections and Colours of Light (Prometheus Books, New York, 2003), 4th ed.
[3] McKay, Samuel, et al. Physical Review Letters 134(9),093803 (2025).

Q 37: Ultra-cold Atoms, Ions and BEC II (joint session A/Q)

Time: Wednesday 14:30–16:30 Location: N 1

Invited Talk Q 37.1 Wed 14:30 N 1

Three-body dynamics between an ion and two Rydberg states — •Jennifer Krauter[1], Maximilian Futterknecht[1], Óscar Andrey Herrera Sancho[1], Florian Anschütz[1], Utzuri Högl Vidal[1], Moritz Berngruber[2], Florian Meinert[1], Robert Löw[1], and Tilman Pfau[1] — [1]5th Institute of Physics, University of Stuttgart, Pfaffenwaldring 57, 70569 Stuttgart — [2]Max Planck Institute of Quantum Optics, Hans-Kopfermann-Str. 1, 85748 Garching

As a versatile tool, our high-resolution ion microscope has sucessfully been used to study the dynamics between bound and unbound Rydberg atom-ion pair states in the ultracold regime. With our experimental apparatus we achieve high temporal and spatial resolution of at least 200 nm, which is well-suited for the real space study of these pair dynamics. Here, we want to show that the binding mechanism between ions and Rydberg atoms is not limited to diatomic molecules but can be extended to polyatomic systems, for which we expect interactions that are even more intricate. We are particularly interested in bound states that comprise two Rydberg atoms and one ion. For this scenario, we predict a rich interaction potential that combines the interaction between induced dipoles, ion-Rydberg atom interactions, and the Rydberg blockade effect, leading to potential wells that support bound molecular states between the three particles. Experimentally, we are working toward realizing and studying these systems both spectroscopically as well as in real space, hoping to gain insight into the underlying fewbody physics.

Q 37.2 Wed 15:00 N 1

Measuring inter-atomic friction with ultracold gases — •Silvia Hiebel, Sabrina Burgardt, Julian Fess, and Artur Widera — RPTU University Kaiserslautern-Landau

Usually, friction is characterized at the macroscopic scale. Over the past 25 years, microscopic measurements have become possible – for example, by dragging single atoms across surfaces with lateral force microscopes or by studying lubricity with dipole potentials acting on trapped ions. Yet, to understand transport in complex media, we also need direct access to friction at the level of individual atoms embedded in a gaseous environment.

We present our measurements of the friction of single atoms in a tilted optical lattice interacting with an ultracold atomic bath. A one-dimensional lattice allows controlled transport of individual atoms with tunable transport parameters, generating well-defined forces that can exceed gravity by several orders of magnitude and enabling access to distinct diffusion regimes. By pulling the single probe atoms through a dense ultracold bath, we observe the interplay between the driven impurity and its environment and extract the resulting effective friction.

Q 37.3 Wed 15:15 N 1

Fast Parallel Atom Sorting for a Rydberg Atom Quantum Computer Demonstrator — •Achim Scholz[1,2], Christopher Bounds[1,2], Manuel Morgado[1,2], Govind Unnikrishnan[1,2], Ralf Berner[1,2], Jiachen Zhao[1,2], Julia Hickl[1,2], Maximilian Kob[1,2], Sebastian Weber[3,2], Hans-Peter Büchler[3,2], Simone Montangero[4], Christoph Tresp[5], Jürgen Stuhler[5], Tilman Pfau[1,2], and Florian Meinert[1,2] — [1]5th Inst. of Physics, University of Stuttgart — [2]IQST — [3]Inst. for Theoretical Physics III, University of Stuttgart — [4]Inst. for Complex Quantum Systems, University of Ulm — [5]TOPTICA Photonics AG

The QRydDemo project aims to realize a Rydberg atom quantum computer demonstrator based on the fine-structure qubit in ^{88}Sr. This qubit not only allows for fast single-qubit gates via strong two-photon Raman transitions but also enables triple-magic trapping at an expected wavelength of 592 nm, for both qubit states and the Rydberg state are magically trapped. These conditions are promising for the realization of high-fidelity multi-qubit operations wherefore we employ a novel all electro-optical tweezer setup comprised of 20 AODs at the triple-magic wavelength. Each AOD can realize a 1D-array with up to 64 tones to finally create a 500 qubit array by folding the independent rows with a three-staged step mirror. Utilizing this architecture, we present our progress on single atom loading and cooling, as well as rearrangement towards sorting and dynamical pattern generation. The availability of fast parallel reshuffling within the qubit coherence time paves the way towards flexible qubit connectivity and operations.

Q 37.4 Wed 15:30 N 1

Towards Commissioning a Linear Surface Trap for Ions with Real-Time Control and Open-Science Workflows — •Tobias Spanke, Frederike Dörr, Florian Hasse, Lucas Eisenhart, Deviprasath Palani, Jörn Denter, Mario Niebuhr, Ulrich Warring, and Tobias Schätz — Physikalisches Institut, Albert-Ludwigs-Universität, Freiburg

We present a modern trapped-ion platform that combines a microfabricated surface-electrode trap, real-time control, and open-science workflows for scalable quantum control and precision collision studies. We report on the commissioning of a linear surface-electrode ion trap from Sandia National Laboratories [1] operated with ARTIQ real-time control and versioned experiment pipelines for experiments with ^{25}Mg$^+$ ions. A stabilized multi-wavelength laser system enables robust loading, Doppler cooling, and coherent control [2]. As a first application, we implement "Phoenix Flyby Calibration", a laser-triggered neutral-gas source for time-resolved benchmarking of ion-neutral collision dynamics in our trapped-ion apparatus. This commissioning lays the groundwork for systematic studies of background-gas-induced heating and loss in surface traps and for transferable protocols for real-time control and open-science workflows in trapped-ion experiments.

[1] Revelle, M. C. (2020), Phoenix and Peregrine Ion Traps, arXiv:2009.02398 [physics.app-ph] (2020)
[2] Palani, D. et al. (2023), High-Fidelity Transport of Trapped-Ion Qubits in a Multi-Layer Array, arXiv:2305.05741 [quant-ph] (2023)

Q 37.5 Wed 15:45 N 1

Ultracold mixture of erbium and lithium atoms — •Kirill Karpov, Alexandre De Martino, Florian Kiesel, Jonas Auch, Eduard Heidt, and Christian Gross — Eberhard Karls Universitaet Tuebingen, Tuebingen, Germany

The extreme mass imbalance between Er and Li offers a unique platform for exploring impurity physics and emergent many-body phenomena. In this experiment, we produce a mixture of ^{166}Er and ^{6}Li. We achieve Bose-Einstein condensation for erbium via evaporative cooling, while lithium is sympathetically cooled by the erbium. Furthermore, the tune-out wavelength of Er enables species-selective confinement. This allows for the far-detuned conservative trapping of Li without perturbing the Er background. Such species-selective trapping schemes open a new level of control in mixture experiments, paving the way for studying the properties of moving Bose polarons.

Q 37.6 Wed 16:00 N 1

Generation of Laughlin states of ultracold atoms exploiting coherent driving — •Alberto Tabarelli de Fatis[1], Iacopo Carusotto[1], Christof Weitenberg[2], Alexander Schnell[3], and André Eckardt[3] — [1]Pitaevskii BEC Center, CNR-INO and Dipartimento di Fisica, Universitá di Trento, Trento, Italy — [2]Department of Physics, TU Dortmund University, 44227 Dortmund, Germany — [3]Institut für Physik und Astronomie, Technische Universität Berlin, Berlin, Germany.

Realizing fractional quantum Hall (FQH) states in a well-controlled environment such as neutral ultracold atoms, has proven extremely challenging, restricting experiments to a very small number of particles N=2,3.

I present a proposal to generate Laughlin states in an FQH system coupled to a BEC reservoir via an angular-momentum-selective coherent pump. By adiabatically varying the strength and detuning of the pump, vacuum is converted into a Laughlin state, without changing the system Hamiltonian, and avoiding gap closing associated with the topological phase transition. This scheme allows the generation of quite large (of order N=10) Laughlin states with excellent fidelity, as well as quasihole excitations on top of it, without fine-tuning of the driving parameters, and with reasonable preparation times.

An experimental realization of our proposal will open new perspectives in the use of ultracold atoms as quantum simulators of condensed matter systems and its extension to non-Abelian states will provide a powerful platform for topological quantum computing.

Q 37.7 Wed 16:15 N 1

Fractal ground state of mesoscopic ion chains in periodic potentials — Raphaël Menu[1], Jorge Yago Malo[2], •Joshua Weissenfels[1], Vladan Vuletić[3], Maria Luisa Chiofalo[2], and Giovanna Morigi[1] — [1]Theoretische Physik, Universität des Saarlandes, D-66123 Saarbrücken, Germany — [2]Dipartimento di Fisica Enrico Fermi, Universita di Pisa and INFN, Largo B. Pontecorvo 3, I-56127 Pisa, Italy — [3]Department of Physics, MIT-Harvard Center for Ultracold Atoms, and Research Laboratory of Electronics, Massachusetts Institute of Technology, Cambridge, Massachusetts 02139, USA

Trapped ions in a periodic potential are a paradigm of a frustrated Wigner crystal. The dynamics are captured by a long-range Frenkel-Kontorova model. We show that the classical ground state can be mapped to the one of a long-range Ising spin chain in a magnetic field, whose strength is determined by the mismatch between the chain's and substrate lattice's periodicity. The mapping is exact when the substrate potential is a piecewise harmonic potential and holds for any two-body interaction decaying as $1/r^\alpha$ with the distance r. We show that the ground state is a devil's staircase of regular, periodic structures as a function of the mismatch and of the interaction exponent α. The predictions of the piecewise parabolic potentials are compared with the case when the substrate is a sinusoidal potential.

Q 38: Precision Spectroscopy of Atoms and Ions III (joint session A/Q)

Time: Wednesday 14:30–16:30 Location: N 3

Invited Talk Q 38.1 Wed 14:30 N 3

Enhanced Sensitivity for Electron Affinity Measurements — •Franziska Maria Maier, Erich Leistenschneider, Lutz Schweikhard, and Stephan Malbrunot-Ettenauer — CERN

The electron affinity (EA) reflects the energy released when an electron is attached to a neutral atom and encodes key information about atomic structure, electron correlation effects and chemical reactivity. However, the EA of the heaviest elements of the periodic table remain experimentally unexplored despite their fundamental importance to benchmark atomic many-body calculations with implications across atomic and nuclear physics, quantum chemistry and radiopharmaceutical research. We have developed a novel technique to determine EAs through Laser Photodetachment Threshold Spectroscopy, performed in an electrostatic ion beam trap, a so called MR-ToF device [1]. Our method increases the sample's exposure to laser photons and, thus, enhances the experimental sensitivity by three orders of magnitude. By applying this technique, we measured the EA of ^{35}Cl to be 3.612720(44) eV, achieving state-of-the-art precision while employing five orders of magnitude fewer anions. This unprecedented sensitivity paves the way for systematic EA measurements across isotopic chains - including isotope shifts and hyperfine splittings - and ultimately for the first direct determination of electron affinities in superheavy elements. This presentation will introduce our novel method and present our experimental results. [1] F. M. Maier, E. Leistenschneider et al., Nat. Commun. 16, 9576 (2025).

Q 38.2 Wed 15:00 N 3

High resolution dielectronic recombination of beryllium-like heavy ions at the CRYRING@ESR storage ring — •Mirko Looshorn[1,2], Carsten Brandau[3], Mike Fogle[4], Jan Glorius[3], Elena Hanu[3,5,6], Volker Hannen[7], Pierre-Michel Hillenbrand[3], Claude Krantz[3], Michael Lestinsky[3], Esther Menz[3,8], Reinhold Schuch[9], Uwe Spillmann[3], Ken Ueberholz[7], Shuxing Wang[1,2], and Stefan Schippers[1,2] — [1]Justus-Liebig-Universität Gießen — [2]Helmholtz Forschungsakademie Hessen für FAIR (HFHF), GSI Helmholtzzentrum für Schwerionenforschung, Darmstadt — [3]GSI Helmholtzzentrum für Schwerionenforschung, Darmstadt — [4]Auburn University — [5]Helmholtz-Institut Jena — [6]Goethe University Frankfurt — [7]Universität Münster — [8]Universität zu Köln — [9]Stockholm University

Electron-ion collision spectroscopy is a powerful tool for studying highly charged ions. The heavy-ion storage ring CRYRING@ESR offers excellent conditions for high-resolution dielectronic recombination (DR) measurements due to its ultra-cold electron cooler. Such high-precision DR spectroscopy enables sensitive tests of higher-order QED contributions in strong fields. We present recent DR studies of heavy berylliumlike systems, including fully evaluated results for Pb^{78+} [1] and measurements of Au^{75+}, which are currently under analysis. Comparisons with state-of-the-art theory highlight the potential of these systems to benchmark precision atomic-structure calculations in the high-Z regime.

[1] S. Schippers et al., Phys. Rev. Lett. **135**, 113001 (2025).

Q 38.3 Wed 15:15 N 3

Adaptive, symmetry-informed Bayesian metrology for precise measurements — •Matt Overton[1], Jesús Rubio[2], Nathan Cooper[1], Janet Anders[3], and Lucia Hackermüller[1] — [1]University of Nottingham, Nottingham, UK — [2]University of Surrey, Guildford, UK — [3]University of Exeter, Exeter, UK

High-precision measurements are crucial for addressing major scientific and technological challenges; however, obtaining these measurements can be time-consuming. Here, we present a systematic strategy for parameter estimation in the low-data limit that integrates experimental control parameters and natural symmetries. The method is guided by a Bayesian quantifier of precision gain, enabling adaptive optimisation tailored to any experiment.

This adaptive strategy is demonstrated in a quantum technology experiment, in which ultracold caesium atoms are confined in a micromachined hole in an optical fibre. We find a five-fold reduction in the fractional variance of the estimated parameter, compared to the standard measurement procedure. Equivalently, our strategy achieves a target precision with a third of the data points previously required. Such enhanced device performance and accelerated data collection will be essential for applications in quantum computing, communication, metrology, and the wider quantum technology sector.

Q 38.4 Wed 15:30 N 3

Resolving the recoil splitting in Doppler-free spectroscopy of calcium in a heat pipe — •Andreas Reuss and Simon Stellmer — Universität Bonn, Germany

Calcium, as an alkaline-earth metal, is of significant interest to both the atomic and nuclear physics communities. The narrow intercombination line at 657 nm is of particular interest and can be probed in a simple vapor cell using Doppler-free saturated absorption spectroscopy to generate a narrow and stable reference signal. However, recoil effects lead to a splitting of the absorption line, introducing a variable asymmetry in the lineshape that degrades the stability of this reference. In this work, we reduce all broadening mechanisms to a level that allows us to resolve the recoil splitting. We lock a laser to one of the recoil components and quantify the frequency stability.

Q 38.5 Wed 15:45 N 3

Development of a cw laser system at 185nm — •Jonas Gottschalk, Sascha Heider, Thorsten Groh, Simon Stellmer, and UVQuanT Consortium — Universität Bonn, Germany

Many of the strong transitions in diatomic molecules with double bonds, such as O_2, N_2 or NO, are located in the vacuum-UV part of the spectrum between 100 and 200 nm. The generation of tunable cw light in this wavelength range remains a major challenge, but recent advancements in laser technology motivate new attempts.

We present a DUV laser system based on two continuous-wave VECSEL lasers, one operating at 431.4 nm via intracavity frequency doubling and the other at 1299.8 nm.

The fundamental waves are combined in a sequence of sum-frequency-generation stages to produce light at 185 nm.

We will use the system to perform spectroscopy on the $^1S_0$ - $^1P_1$ transition of mercury and to explore molecular oxygen lines in the Schumann-Runge bands, with implications for fundamental physics and astrochemistry.

Q 38.6 Wed 16:00 N 3

A single frequency continuous wave OPO laser as powerful and flexible tool for high resolution spectroscopy — •Jakob Weiss[1], Katrin Weidner[1], Raphael Hasse[1], Thorben Niemeyer[1], Matou Stemmler[1], Klaus Wendt[1], and Sapida Akhundzada[2] — [1]Johannes Gutenberg-Universität Mainz — [2]Hübner GmbH & Co. KG, Division HÜBNER Photonics, Kassel

Optical parametric oscillators (OPOs) pumped at 780 nm provide widely tunable laser radiation, covering almost the entire spectral range from 510 nm up to 3400 nm (including SHG). The possibility of automated continuous wave operation with line widths in the order of 1 MHz makes them extremely versatile tools for precision spectroscopy. Remaining limitations in the width and speed of continuous frequency scanning as well as coarse linewidth adjustment over large spectral ranges are presently addressed for enabling specific spectroscopic applications in atomic and molecular spectroscopy.

Feasibility studies are carried out using the C-WAVE GTR (HÜBNER Photonics) for investigations on the hyperfine structure of Fe isotopes by resonance ionization spectroscopy and in photodetachment studies on molecules, for which in both cases a smooth and well controlled tuning behavior of the laser frequency is a fundamental requirement. For this purpose a continuous, high-resolution fine-range scan mode as well as a wide-range coarse-scan algorithm have been developed to provide quick and flexible wavelength access, enhancing the versatility of the C-WAVE GTR and its suitability for advanced spectroscopic applications.

Q 38.7 Wed 16:15 N 3

A robust technique for ground-state cooling of antimatter in cryogenic multi-Penning traps — •Nikita Poljakov[1], Philipp Hoffmann[1], Marek Prasse[1], Jan Schaper[1], Julia Coenders[1], Juan Manuel Cornejo[2], Klemens Hammerer[3], Stefan Ulmer[4,5], and Christian Ospelkaus[1,6] — [1]Leibniz Universität Hannover, Germany — [2]Universidad de Cádiz, Spain — [3]Universität Innsbruck, Austria — [4]Ulmer Fundamental Symmetries Laboratory, RIKEN, Japan — [5]Heinrich-Heine-Universität Düsseldorf, Germany — [6]Physikalisch-Technische Bundesanstalt, Braunschweig, Germany

Within the BASE collaboration, we deployed a cryogenic multi-Penning trap to contribute to high-precision (anti-)proton g-factor measurements[1,2] to test CPT symmetry via quantum logic spectroscopy (QLS)[3] with a $^9Be^+$ cooling and logic ion. After demonstrating key steps - optical sideband spectroscopy[4], ground-state cooling[5] of a $^9Be^+$ ion, and fast adiabatic transport[6] - we turn to ground-state cooling of the (anti-)proton. We simulate its Coulomb coupling to a $^9Be^+$ ion in a double-well potential in a microfabricated Penning trap. The 9:1 mass ratio causes anharmonicities that hinder cooling of 4 K (anti-)protons under static potentials. A frequency sweep of the $^9Be^+$ well maintains resonance and enables ground-state cooling. This technique is also applicable to other laser-inaccessible (anti-)particles. [1]G. Schneider et al., Science 358 (2017) [2]C. Smorra et al., Nature 550 (2017) [3]P. Schmidt et al., Science 309 (2005) [4]J. Cornejo et al., Phys. Rev. Res. 6 (2023) [5]J. Cornejo et al., Phys. Rev. Res. 6 (2024) [6]M. Boehn et al., Comms. Phys. 8 (2025).

Q 39: Poster – Cold Molecules (joint session MO/Q)

Time: Wednesday 17:00–19:00 Location: Philo 1. OG

Q 39.1 Wed 17:00 Philo 1. OG

Progress on Zeeman slowing CaF — •Julius Niederstucke, Timo Poll, Paul Kaebert, Sebastian Anskeit, Mirco Sierke, and Silke Ospelkaus — Leibniz Uni Hannover

Significant advancements have recently been achieved in direct laser cooling of molecules, bringing them to temperatures near absolute zero [1, 2]. However, the number of molecules that can be captured from molecular beams using conventional laser cooling methods remains a limiting factor in such experiments [3, 4]. In this work, we present strategies to enhance the yield of molecules in such experiments. To this end, we present our experimental findings on the Zeeman slower developed for directly laser-coolable molecules, as proposed by our group [5], and outline the initial steps towards creating a sub-Doppler engineered red magneto-optical trap [6,7]. [1] J. F. Barry et al. 2012 [2] Y. Wu et al. 2021 [3] S. Truppe et al. 2017 [4] L. Anderegg et al. 2017 [5] M. Petzold et al. 2018 [6] S. Xu et al. 2021 [7] S. Xu et al. 2022

Q 39.2 Wed 17:00 Philo 1. OG

Towards laser cooling of NH radical — •Ashish Mahangare, Daniel Roesch, and Edvardas Narevicius — TU Dortmund, Germany

Ultra-cold molecules open up a wide variety of applications like quantum control, ultra-cold chemical dynamics, quantum information, tests of fundamental constants and precision measurements. Laser cooling has been applied for a few diatomic molecules such as SrF, CaF and YO, YbF, AlF, BaF and a poly-atomic molecule CaOH.

Our goal is to laser cool ^{15}NH. The main transition of interest for laser cooling is $(X^3\Sigma^-)(v" = 0, N" = 1, J" = 1)$ to $A^3\Pi(v' = 0, N' = 1, J' = 0)$ at 336 nm. The excited state of this cooling transition has a lifetime of around 400 ns. This electronic transition is rotationally closed and has highly diagonal FCFs.

We performed laser-induced fluorescence (LIF) to study the hyperfine structure of laser cooling transition. I will also present Terahertz rotational spectroscopy to pump molecules from N = 0 to N =1 state. Terahertz spectroscopy is also performed to get highly precise hyperfine splitting in N = 0 and N = 1 rotational states for $X^3\Sigma^-$.

Q 39.3 Wed 17:00 Philo 1. OG

Collisions in a quantum gas of bosonic ^{23}Na^{39}K molecules — •Fritz von Gierke[1], Mara Meyer zum Alten Borgloh[1], Jule Heier[1], Philipp Gersema[1], Kai Konrad Voges[2], Baraa Shammout[1], Eberhard Tiemann[1], Leon Karpa[1], and Silke Ospelkaus[1] — [1]Institut für Quantenoptik, Leibniz Universität Hannover — [2]Centre for Cold Matter, Blackett Laboratory, Imperial College London

We present our latest experimental results on ultracold NaK quantum gases, focusing on atom-molecule and molecule-molecule collisions. In particular, we report recent advances in the electric field control of atom-molecule Feshbach resonances and shielding of collisions with implications for future quantum simulations and many-body physics.

Q 39.4 Wed 17:00 Philo 1. OG

Crystal-to-droplet melting in ultracold polar molecules — •William Freitas, Panagiotis Giannakeas, and Jan M Rost — Max Planck Institute for the Physics of Complex Systems, Dresden, Germany

Microwave-shielded polar molecules provide a novel platform for exploring dipolar matter in the strongly correlated regime, where dipole-dipole interactions naturally confine molecular ensembles to quasi-two-dimensional geometries. The competition between the long-range antidipolar attraction and the anisotropic short-range repulsion leads to a rich variety of phases, ranging from quantum droplets to crystalline structures.

In this work, we investigate the transition between the crystal and droplet phases, focusing specifically on the melting of crystalline order for finite systems. For systems of up to N = 40 molecules, we observe that the system develops droplet-ring configurations as an intermediate state between the droplet and crystal phases, characterized by a superfluid fraction below unity. Moreover, we show that the droplet-ring state retains six-fold symmetry, a fingerprint of the underlying crystal structure, as demonstrated by the pair-correlation function and structure factor.

Our simulations employ the Variational Monte Carlo method with a neural-network quantum state as the trial wave function. This approach provides a highly flexible functional form and enables stable energy minimization, yielding an accurate description of the ground state and an efficient treatment of strongly correlated finite systems.

Q 39.5 Wed 17:00 Philo 1. OG

Towards laser cooling of NH radical — •Ashish Mahangare, Daniel Roesch, and Edvardas Narevicius — TU Dortmund, Germany

Ultra-cold molecules open up a wide variety of applications like quantum control, ultra-cold chemical dynamics, quantum information, tests of fundamental constants and precision measurements. Laser cooling has been applied for a few diatomic molecules such as SrF, CaF and YO, YbF, AlF, BaF and a poly-atomic molecule CaOH.

Our goal is to laser cool ^{15}NH. The main transition of interest for laser cooling is $X^3\Sigma^-(v" = 0, N" = 1, J" = 1)$ to $A^3\Pi(v' = 0, N' = 1, J' = 0)$ at 336 nm. The excited state of this cooling transition has a lifetime of around 400 ns. This electronic transition is rotationally closed and has highly diagonal FCFs.

We performed laser-induced fluorescence (LIF) to study the hyperfine structure of laser cooling transition. I will also present Terahertz rotational spectroscopy to pump molecules from N = 0 to N =1 state. Terahertz spectroscopy is also performed to get highly precise hyperfine splitting in N = 0 and N = 1 rotational states for $X^3\Sigma^-$.

Q 40: Poster – Photonics

Nanophotonics; 3D Printing; Microscopy; Biophotonics; General Photonics

Time: Wednesday 17:00–19:00 Location: Philo 1. OG

Q 40.1 Wed 17:00 Philo 1. OG

Photonic integrated top-hat beam profiler for multi-ion clock application — •Matthias Ludwig[1,2], Carl-Frederik Grimpe[1], Guochun Du[1], Fatemeh Salahshoori[1], André Kulosa[1], Elena Jordan[1], and Tanja E. Mehlstäubler[1,3,4] — [1]Physikalisch-Technische Bundesanstalt, Braunschweig, Germany — [2]Karlsruhe Institute of Technology (KIT), Karlsruhe, Germany — [3]Leibniz Universität Hannover, Institut für Quantenoptik, Hannover, Germany — [4]Leibniz Universität Hannover, Laboratorium für Nano- und Quantenengineering, Hannover Germany

Multi-ion optical clocks offer improved precision by reducing the averaging time. To minimise intensity-dependent AC Stark shifts on individual ions, highly homogeneous illumination is essential. The optimal beam shape for this purpose is a top-hat intensity profile. This has previously been achieved using holographic waveplates in free space, but this approach limits spatial uniformity [1]. We demonstrate that an extreme mode converter, implemented on an Al_2O_3 photonic material platform, can generate this top-hat profile for the 370 nm Doppler cooling transition of Yb^+ ions, thereby increasing the modal area of the waveguide mode by a factor of $\sim 10^4$. This integrated photonic approach provides a path towards improved beam homogeneity and scalable multi-ion clocks, overcoming the limitations imposed by free-space optics.

[1] J. Yu et al., "Precision Spectroscopy in Yb+ ions," 2024 European Frequency and Time Forum (EFTF), Neuchâtel, Switzerland, 2024, pp. 334-336, doi: 10.1109/EFTF61992.2024.10722611.

Q 40.2 Wed 17:00 Philo 1. OG

Fabrication approach for all-diamond nano-cavity structures in submicron membranes — •Kilian Mark, Jan Fait, and Christoph Becher — Universität des Saarlandes, Campus E2.6, 66123 Saarbrücken, Germany

Tin-vacancy (SnV) centers in diamond combine excellent optical properties with long spin-coherence times, making them promising candidates for spin-photon interfaces in quantum technologies [1]. However, photon collection efficiency from bulk diamond is low due to total internal reflection at the diamond-air interface [2]. It is crucial for most applications to improve the collection efficiency of photons, which can be achieved by using nanophotonic structures. This contribution presents the individual fabrication steps towards bull's eye cavities in thin diamond membranes, focusing on the use of a thin silicon (Si) layer as a hard mask to etch the diamond via inductively coupled plasma reactive ion etching (ICP-RIE). The Si layer is patterned in an SF_6:C_4F_8 plasma to obtain sharp features with vertical sidewalls, which are subsequently transferred into the diamond using an Ar:O_2 plasma. *Tests on bulk diamond with feature dimensions adapted to the SnV emission wavelength (619 nm) show promising results with steep angles and small roughness of the sidewalls. We will report on first experiments on deterministic implantation of SnV centers at the center of the bullseye structures. *[1] J. Görlitz et al., npj Quantum Inf 8(45), 2022 *[2] E. Janitz et al., Optica 7(10), 2020

Q 40.3 Wed 17:00 Philo 1. OG

Passive photonic structures in transition metal dichalcogenides for integrated quantum photonics — •Anita Kohlwes[1], Zengya Li[2], Timur Shegai[2], and Doris Reiter[1] — [1]TU Dortmund, Germany — [2]Chalmers University of Technology, Gothenburg Sweden

Integrated photonics relies on nanostructured materials, including single-photon emitters, waveguides, and photonic cavities. While most existing approaches use different materials for the various components, we aim to realize a single-material, all-in-one photonic platform based on transition-metal dichalcogenides (TMDCs). With this goal in mind, we simulate passive photonic TMDC structures using Maxwell solvers such as FDTD or FEM and optimize their performance. The first part of the study examines simple rectangular waveguides and how geometry affects mode confinement, effective index, and propagation. From this, we derive clear design rules toward experiments that maximize performance while remaining compatible with planar processing. In the second part, we introduce a periodic array of holes in the waveguide to create a photonic bandgap. By tuning the period and hole diameter, we design efficient mirrors and a stopband at the target wavelength for TMDC single-photon emitters. Our results represent a first step towards a single-material TMDC photonic platform.

Q 40.4 Wed 17:00 Philo 1. OG

Cryogenic-Temperature ODMR Analysis of Nitrogen-Vacancy Centers in Nanodiamonds — •Wanrong Li[1], Keisuke Oshimi[2], Masazumi Fujiwara[2], and Oliver Benson[1] — [1]Humboldt-Universität, Berlin, Germany — [2]Okayama University, Okayama, Japan

Nitrogen-Vacancy (NV) defect centers in diamond have demonstrated remarkable quantum properties and have enabled diverse applications in quantum technology and sensing. NV centers in nanodiamond exhibit temperature-dependent shifts in their zero-field splitting (ZFS), but the underlying mechanisms may differ from those observed in bulk diamond [1] due to surface effects [2], lattice strain, impurity-induced perturbations, and other nanoscale mechanisms. In this work, we investigate the Optically Detected Magnetic Resonance (ODMR) of ensemble NV centers in nanodiamond over a range of cryogenic temperatures. These measurements enable direct probing and modeling of the temperature-dependent NV zero-field splitting. Looking ahead, we aim to investigate fundamental physical phenomena in nanodiamond using single NV defects.

References

[1] M. C. Cambria et al., Physically motivated analytical expression for the temperature dependence of the zero-field splitting of the nitrogen-vacancy center in diamond, Phys. Rev. B 108, L180102 (2023).

[2] M. Sow et al., Millikelvin intracellular nanothermometry with nanodiamonds, Adv. Sci. 12, e11670 (2025).

Q 40.5 Wed 17:00 Philo 1. OG

Light modulation in electrically switchable metasurfaces using organic electro-optical materials — •Paul Bingel[1], Monika Ubl[1], Masis Sirim[2], Patrick Kern[2], Stefan Bräse[2], and Harald Giessen[1] — [1]4th Physics Institute and Research Center SCoPE, University of Stuttgart, Germany — [2]Institute of Organic Chemistry, Karlsruhe Institute of Technology (KIT), Germany

Classical electro-optic materials, including liquid crystals, transition-metal oxides, and conducting polymers, are widely used in display technologies, adaptive optics, and tunable photonic systems. Recently developed organic-electro-optic (OEO) materials have demonstrated coefficients more than an order of magnitude higher than those of conventional systems. This advancement enables the integration of plasmonic metasurfaces with the high-performance OEO chromophore JRD1 to realize electrically switchable devices based on the Pockels effect. In this presentation, we demonstrate that a gold metasurface coated with JRD1 exhibits strong and fast electro-optic tunability. By tailoring the metasurface geometry, we achieve exceptionally high transmission modulation in the infrared, particularly at technologically relevant telecom wavelengths. These active hybrid structures offer a promising route toward compact, efficient, and reconfigurable components for next-generation photonics and telecommunications.

Q 40.6 Wed 17:00 Philo 1. OG

Enhancing Light-Matter Interactions In Integrated Platforms — •Malaika Waheed[1], Christian Koller[1], and Sarah Margaretha Bayer-Skoff[2] — [1]FH Wiener Neustadt, Johannes Gutenberg-Straße 3, 2700 Wiener Neustadt 2700 Wiener Neustadt, Austria — [2]TU Wien, Stadionallee 2, 1020 Wien, Austria

Two-dimensional van der Waals materials, such as hexagonal boron nitride hosting carbon-related defects, represent a versatile platform for quantum technologies at room temperature. These defects offer the properties of emitting single photons, as well as they offer optically detectable spin resonances under controlled environment. Also, the single-photon detection and correlation need to be measured with high time resolution to improve the quantum efficiency and fast detection. Thus, our work presents the study of carbon-related point defects in hBN, including single photon emission and their optically detectable magnetic resonances. For the detection system of these single photons, the design and characterization of an on-chip CMOS-compatible single photon detector with an integrated correlator module is important to implement. With on-chip detector design and behavioural analysis of point defects in hBN, this work will potentially contribute towards scalable, high-performance solutions for quantum photonics and sensing applications.

Q 40.7 Wed 17:00 Philo 1. OG

Optical feedback for the photo-induced deformation of thin films — •Kenneth Lütticke and Carsten Henkel — Universität Potsdam, Institut für Physik und Astronomie, Germany

Photo-induced deformations in photoactive polymer thin films have been intensively studied for decades due to their potential use in inscribing topographical relief patterns with high information density. These deformations arise from trans–cis photoisomerization cycles, and various theoretical models have been developed to bridge the molecular processes with the resulting macroscopic structures [1,2,3]. While several theoretical frameworks address mass transport or anisotropic reorientation [4,5], they fall short of predicting realistic deformation scales or feedback effects during holographic exposure. In this work, we analyze the possibility of an optical feedback where holographic illumination gets reinforced by the growing relief, as an alternative to the conventional orientation approach.

[1] M. Saphiannikova, V. Toshchevikov and N. Tverdokhleb, Soft Matter 20 (2024) 2688
[2] M. Merkel, A. Elizabeth, M. Böckmann, H. Mönig, C. Denz and N. L. Doltsinis, J. Chem. Phys. 158 (2023) 104905
[3] H. Leblond, R. Barille, S. Ahmadi-Kandjani, J.-M. Nunzi, E. Ortyl and S. Kucharski, J. Phys. B 42 (2009) 205401
[4] F. Ledoyen, P. Bouchard, D. Hennequin and M. Cormier Phys. Rev. A 41 (1990), 4895
[5] M. Saphiannikova, V. Toshchevikov, and J. Ilnytskyi, Nonlin. Opt. Quantum Opt. 41 (2010) 27

Q 40.8 Wed 17:00 Philo 1. OG

Polarization measurements of nanophotonic outcouplers for quantum technology applications — •Nasimalsadat Mousavi Savadkouhi[1], Carl-Frederik Grimpe[2], Guochun Du[2], Steffen Sauer[1,3], Anastasiia Lüssmann-Sorokina[1,3], Afonso Alcape Meyer[1,3], Liam Shelling Neto[1,3], Elena Jordan[2], Tanja E. Mehlstäubler[2,4,5], and Stefanie Kroker[1,2,3] — [1]Institut für Halbleitertechnik, Technische Universität Braunschweig, Germany — [2]Physikalisch-Technische Bundesanstalt, Braunschweig, Germany — [3]Laboratory for Emerging Nanometrology, Braunschweig, Germany — [4]Institut für Quantenoptik, Leibniz Universität Hannover, Germany — [5]Laboratorium für Nano- und Quantenengineering, Hannover, Germany

Controlling the polarization state of light is crucial for photonic and quantum optical applications, such as cooling and state preparation of ions for quantum computing and quantum sensing. Integrated nanophotonic outcouplers provide an on-chip interface for directing light fields onto these quantum emitters, making their ability to generate well-defined circular polarization important. In this work, we investigate the polarization of light emitted from an outcoupler at 760 nm based on a QR-Code structure. We use a rotating quarter-wave plate method to characterize the polarization state, reconstruct the set of Stokes parameters, and obtain the degree of linear and circular polarization of the outcoupled beam. We demonstrate that this measurement method enables verification of the circular polarization by the outcoupler and allows quantification of polarization imperfections.

Q 40.9 Wed 17:00 Philo 1. OG

Simulation Framework for Athermal Silicon Nitride Waveguide Design — •Ekin Bircan Bosdurmaz, Max de Jager, and Pepijn W. H. Pinkse — MESA+ Institute for Nanotechnology, University of Twente, PO Box 217, 7500 AE Enschede, The Netherlands

We present a simulation framework to engineer athermal integrated waveguides in silicon nitride photonic platforms. Starting from realistic Si_3N_4/SiO_2 stacks with optional overlay layers, we compute the temperature dependence of the guided modes by combining electromagnetic eigenmode solvers with temperature-dependent refractive index models. Thermo-optic finite-element simulations provide the local temperature distribution allowing us to find contributions to the effective index shift. By sweeping core geometry, cladding composition, and overlay thickness, we map the design space where the net thermo-optic coefficient of the fundamental mode approaches or crosses zero, and we quantify the spectral bandwidth over which this athermal condition is maintained. The methodology provides a practical, simulation-driven route to identify and optimize athermal Si_3N_4/SiO_2 waveguide geometries for temperature-stable operation in precision photonic integrated circuits.

Q 40.10 Wed 17:00 Philo 1. OG

Fabrication of High Quality Factor Resonators in Ta_2O_5 for Integrated Nonlinear Photonics — •Jan Wulkotte[1,2,3], David Lemli[1,2,3], Tim Buskasper[1,2,3], and Carsten Schuck[1,2,3] — [1]Department for Quantum Technology, University of Münster, Heisenbergstr. 11, 48149 Münster, Germany — [2]Center for Soft Nanoscience, Busso-Peus-Str. 10, 48149 Münster, Germany — [3]Center for Nanotechnology, Heisenbergstr. 11, 48149 Münster, Germany

Integrated nonlinear photonics enables the generation of quantum light through sub-wavelength waveguide confinement and high-quality-factor resonators to enhance nonlinear light-matter interactions. Within this framework, tantalum pentoxide (Ta_2O_5) has emerged as a compelling material platform owing to its high refractive index, low propagation loss, and strong third-order optical nonlinearity.

Efficient nonlinear processes require precise dispersion engineering, which necessitates the use of thick films and introduces substantial nanofabrication challenges. In this work, we demonstrate microring resonators with high quality factors at 1550 nm based on 600 nm-thick Ta_2O_5 films on SiO_2 substrates with air cladding. In addition, we show an efficient coupling scheme based on polymer-printed couplers with minimal simulated back reflection, which is expected to facilitate precise control of Kerr nonlinear dynamics.

These high-quality-factor Ta_2O_5 microring resonators constitute a key building block for integrated nonlinear and quantum photonic circuits, paving the way toward on-chip Kerr nonlinear processes and the generation of non-classical states of light.

Q 40.11 Wed 17:00 Philo 1. OG

Enhanced light matter interaction for quantum technologies and sensing applications — •Adam Lafferty, Raphael Neubacher, Helmut Hörner, Malaika Waheed, Ambika Shorny, Fritz Steiner, Alex Götz, Adarsh Prasad, Stefan Walser, and Sarah M. Skoff — Atominstitut, TU Wien, Stadionallee 2, 1020 Vienna, Austria

Strong light-matter interactions are important both for quantum networks and for sensing applications.

Achieving such coupling has long been a challenge for conventional bulk optical platforms. Recent advances in nanofabrication have opened the door to nanophotonics as a powerful platform for enhancing light matter interaction. Here, we will show how different types of nanophotonics can be employed to enhance the interaction between single quantum emitters and a light field. We will also show that such platforms can be employed for sensing applications, even in the wider context of environmental sensing, where we have demonstrated that we can detect and identify nanoplastic particles down to sizes of 100nm.

Q 40.12 Wed 17:00 Philo 1. OG

Investigating Non-Hermiticity in Photonic Waveguides With Higher Modes — •Sabrina Hammel, Julian Schulz, and Christina Jörg — Physics Department and Research Center OPTIMAS, RPTU Kaiserslautern-Landau, Germany

Non-Hermitian photonic systems host a range of striking physical phenomena - such as loss-induced topological states, exceptional points, and non-orthogonal mode dynamics - that are impossible in Hermitian settings [1]. These effects are typically realized by engineering spatial distributions of gain and loss. Here, we demonstrate a fundamentally different and highly versatile approach: implementing non-Hermiticity directly in the orbital degree of freedom. Using 3D micro-printed inverse waveguides infiltrated with absorptive materials, we create photonic structures that support both the fundamental mode (TEM_{00}) and higher-order transverse modes. Certain geometries, such as an elliptical shape, allow the orthogonal TEM_{10} and TEM_{02} modes to couple between neighboring sites, while experiencing different amounts of absorption. This mode-dependent loss produces a non-Hermitian two-mode system without requiring spatially patterned gain or loss. Crucially, because the non-Hermiticity resides in the modal degree of freedom, it can be externally switched simply by choosing which mode is guided. This enables a new class of reconfigurable non-Hermitian photonic platforms capable of realizing and dynamically controlling non-Hermitian phenomena, including exceptional points and loss-stabilized topological states.

[1]: S. K. Gupta et al., Adv. Mater. 32, 1903639 (2020)

Q 40.13 Wed 17:00 Philo 1. OG

The SSH model in non-dimerized chains via multimode waveguides — •Ian Heil, Julian Schulz, and Christina Jörg — Physics Department and Research Center OPTIMAS, RPTU Kaiserslautern-Landau

Topological photonic waveguide arrays based on the Su-Schrieffer-Heeger (SSH) model typically rely on an alternating spacing between neighboring waveguides. Therefore, the distinction between the trivial and topological phases is sensitive to the geometric layout and the presence or absence of individual sites. In this work, we introduce a fundamentally different strategy. We investigate a non-dimerized chain of multimode waveguides whose elliptical geometry enables control over the coupling between s-, p-, and d-like modes [1]. Here, the topology arises because two distinct transverse modes form an effective two-site basis within each real-space waveguide, yielding a synthetic dimerization even though the physical lattice contains only a single site per unit cell. This effective model reproduces SSH-like physics without requiring any spatial alternation of waveguide positions. Because the topological phase is encoded in the modal degrees of freedom rather than real-space geometry, edge states persist regardless of the number of waveguides, and adding or removing sites at the boundaries does not affect the topological character. Through changes in ellipticity or spacing between waveguides, we demonstrate controllable transitions between trivial and topological phases. This mode-based strategy offers a route to reconfigurable topological photonic systems.

[1] G. Liu et al. PRB 110, 214110 (2024)

Q 40.14 Wed 17:00 Philo 1. OG

Integrated Optics for efficient Fluorescent collection for single NV centers — •Robert Bruss[1], Lucas Kirchbach[1,2], and Andreas Stute[1,2] — [1]Faculty AMP, Keßlerpl. 12, 90489 Nürnberg — [2]Faculty EFI, Wassertorstr. 10, 90489 Nürnberg

Efficient collection of fluorescence light is essential for all optically adressable qubit platforms. For the nitrogen-vacancy (NV) center in diamond, the high refractive index of the host medium poses a major challenge as it limits the solid angle under which fluorescence light can leave the crystal. To enhance collection efficiency from single NV centers, we design and simulate micro-optical elements that shall be directly fabricated on the diamond surface using two-photon polymerization. Several optical designs and photoresists are evaluated for their expected coupling efficiency into single-mode fibers and their tolerance to fabrication errors. Additionally, an analytical solution for single lens collimation of the emission of a point source in diamond at a specific wavelength is presented, as well as considerations regarding the degradation of wavefront quality in multi-wavelength Fresnel designs.

Q 40.15 Wed 17:00 Philo 1. OG

Refractive index characterization and luminescence spectra of photoresists for 3D printing — •Leonardo Guimaraes, Leander Siegle, and Harald Giessen — 4th Physics Institute and Research Center SCoPE, University of Stuttgart, Pfaffenwaldring 57, 70569 Stuttgart, Germany

With the development of two-photon polymerization 3D printers, optical and mechanical characterization of their printing material, the photoresist, became crucial. Properties such as transmission have been well characterized recently. The luminescence of these photoresists, of major interest for biomedicine and quantum applications, however, has been underreported. In this work, we characterize the spectral response at multiple excitation wavelengths in the ultra-violet and visible. The refractive index of these photoresists is a key parameter for any optical component. We measure the refractive index of several photoresists over the visible and near-infrared spectral region. Our data shortens the search for the ideal photoresist across a different range of applications, be it the required low autofluorescence necessary for biomedicine, quantum light devices, or optimal refractive index for micro-optical components.

Q 40.16 Wed 17:00 Philo 1. OG

Complex-structured beam produced by modulated phase mask — •Zihao Zhang and Harald Giessen — 4th Physics Institute and Research Center SCoPE, University of Stuttgart, Germany

Super-resolution technologies for both imaging and measurement have become major research frontiers over the past decade, driven by advances such as Stimulated Emission Depletion (STED) microscopy and Structured Illumination Microscopy (SIM). STED routinely achieves resolutions down to 30 nm with strong depletion, while SIM offers enhanced resolution with compatibility for live-cell imaging. However, both methods rely on complex-structured beams, typically donut-shaped or otherwise spatially engineered, whose generation often requires bulky and intricate optical assemblies. Many practical applications, therefore, demand compact, easily integrated solutions for producing such illumination fields. In this work, we exploit state-of-the-art Two-Photon Grayscale Lithography (2GL) to fabricate customizable, continuous, and freeform microscale phase masks capable of generating advanced beam profiles. We demonstrate multiple design strategies, including aspect-ratio tuning, controlled phase-rotation gradients, and phase extraction from superposed fields. These approaches enable the realization of complex-structured beams in a highly compact form factor, suitable for straightforward implantation into existing optical systems. Our results establish 2GL-fabricated phase masks as a versatile platform for next-generation super-resolution illumination engineering.

Q 40.17 Wed 17:00 Philo 1. OG

Mid- to long-wave-infrared nanoscopy with lanthanide transducers — •Junyu Guan[1], Hanyu Zhang[1], Yanan Li[2], Kun Huang[2], and Kangwei Xia[1] — [1]Laboratory of Spin Magnetic Resonance, School of Physical Sciences, University of Science and Technology of China — [2]State Key Laboratory of Precision Spectroscopy, East China Normal University

Mid- to long-wave infrared (MIR-LWIR) microscopy provides a non-invasive and label-free tool to acquire rich spectroscopic and structural information about chemical materials and biomedical samples. However, the lateral resolution is typically limited by severe optical diffraction at long infrared wavelengths, which hinders imaging systems from observing intricate details beyond the diffraction limit. Here, we report a MIR-LWIR to near infrared (NIR) transducer based on a rare-earth-doped crystal, which enables room-temperature MIR-LWIR imaging within a broad spectral coverage of 7-10.6 μm. The presented lanthanide-based transducer is compatible with close positioning to nano-/micro-structures, facilitating near-field MIR-LWIR imaging with an improved spatial resolution from 50 μm to sub-μm. Notably, hidden objects can be accurately identified with high axial precision owing to the confocal excitation configuration, which enables high-resolution MIR-LWIR depth imaging. In addition, experimental validation using two-dimensional materials such as hexagonal boron nitride reveals distinct MIR-LWIR response characteristics, demonstrating the system's capability for high-resolution imaging and spectroscopic characterization across extended infrared wavelengths.

Q 40.18 Wed 17:00 Philo 1. OG

Machine learning driven texture analysis of laser speckle imaging for early breast cancer detection — •Doaa Youssef — Department of Engineering Applications of Lasers, National Institute of Laser Enhanced Sciences (NILES), Cairo University, Egypt

Breast cancer remains one of the most prevalent malignancies, and early detection is crucial for improving patient outcomes. We present an image-guided breast cancer detection method based on laser speckle imaging and machine learning. The approach exploits the distinct absorption and scattering properties of healthy and malignant breast tissue. A dual-wavelength optical system using low-power 532 nm and 632 nm lasers was developed to record speckle patterns from ex vivo breast samples. Diagnostic information is extracted using a strategy that combines multi-neighborhood local entropy with a Gabor filter bank to generate texture maps that reveal subtle structural changes. These maps are fused to form a single informative image, from which texture features are obtained using two histogram-based methods and refined through data reduction techniques. The discriminative capability of the extracted features was assessed using three supervised classification models: support vector machine (SVM), ensemble k-nearest neighbor (E-kNN), and extreme gradient boosting (XGB). Combining information from both wavelengths improved overall diagnostic performance, yielding an accuracy of 98.48% and a weighted F1 score of 98.54%. These findings demonstrate the potential of laser speckle-based optical diagnostics integrated with AI for affordable, non-destructive early breast lesion detection.

Q 40.19 Wed 17:00 Philo 1. OG

Fiber Fabry-Perot Cavities: Design, Arrays, and Interfaces — •Jana Blechmann, Daniel Stachanow, Lukas Tenbrake, Florian Giefer, Gian-Marco Schnueriger, Hannes Pfeifer, and Sebastian Hofferberth — Institute of Applied Physics, University of Bonn, Germany

Fiber Fabry-Perot cavities (FFPCs) offer many advantages, including their miniature size and robustness, in applications like sensing. In the Bonn Fiber Lab, we specialize in the precise fabrication and analysis of FFPCs and the integration with fiber interfaces.

This poster will showcase three ongoing projects, focusing on both the development of fiber cavities and their applications.

We will present our current research on a novel, monolithic, passively stable, fiber-based crossed-cavity, including the manufacturing of fiber mirrors with the in-house shooting setup.

Further, we will showcase our recent steps in manufacturing cavity arrays on optical multicore fibers. Among the numerous possible applications, we aim to use them as an interface for mechanical metamaterials.

We will also present our latest progress in the investigation of interfaced micro-mechanical resonators fabricated through 3D direct laser writing, covering techniques for optimizing Q-factors, such as dissipation dilution and the use of glassy structures with inherently higher intrinsic Q.

Q 40.20 Wed 17:00 Philo 1. OG

Rydberg quantum optics based on integrated photonic waveguides immersed in a hot atomic vapor — •Alexandra Köpf[1,2], Annika Belz[1], Xiaoyu Cheng[1], Benyamin Shnirman[1,2], Hadiseh Alaeian[3], Harald Kübler[1], Robert Löw[1], and Tilman Pfau[1] — [1]5. Physikalisches Institut and Center for Integrated Quantum Science and Technology, Universität Stuttgart, Germany — [2]Institut für Mikroelektronik Stuttgart (IMS-Chips), Stuttgart, Germany — [3]Departments of Electrical & Computer Engineering and Physics & Astronomy, Purdue University, West Lafayette, USA

The combination of thermal atomic vapors with nanophotonic structures provides a unique platform for the exploitation of atom-photon and light induced atom-atom interactions. One major goal is to enhance the corresponding non-linearities from the few to the single photon level by either strong enough coupling or the Rydberg blockade effect. In detail, we study a chip-scale platform based on silicon nitride waveguides integrated into a rubidium vapor cell where the evanescent fields of the photonic waveguides can interact with the atoms in specific regions. By underetching the structures we can further enhance the coupling of the evanescent fields with the atomic vapor. The main focus lies currently in the combination of underetched tapered waveguides with high resolution spectroscopy. In a first experiment it was shown that the transit time broadening is reduced to a level, that sub-Doppler features can be observed, such as EIT. In a second approach we excite Rydberg atoms (in the 32S state) within the evanescent field of a tapered nanowaveguide.

Q 40.21 Wed 17:00 Philo 1. OG

Simulations of inverse taper structures for efficient edge coupling in TFLN — •Micha Jonas, Filip Sosnicki, Laura Padberg, Harald Herrmann, and Christine Silberhorn — Paderborn University, Integrated Quantum Optics, Institute for Photonic Quantum Systems (PhoQS), Warburger Str. 100, 33098 Paderborn, Germany

Thin-film lithium niobate (TFLN) emerges as a promising platform for photonic integrated circuits due to notably electro-optic and nonlinear properties. It makes it particularly suitable for quantum photonics where one can apply frequency-mixing schemes or electro-optic modulation to single-photon pulses. Such applications require low losses within a broad spectral bandwidth. Currently, in- and out-coupling efficiencies are fundamental limitations due to the mode-mismatch of waveguide eigenmodes (MFD ca. $1\mu m$) and fiber mode (MFD ca. $10\mu m$). Here we investigate inverse tapers that enlarge the optical mode at the waveguide facet to match it to the fiber mode increasing coupling efficiency. We perform numerical simulations of taper structures in TFLN to optimize fiber in- and out-coupling of a waveguide. For this purpose, we use Eigenmode Expansion (EME) to calculate the optical mode distribution at the end of the taper while varying its dimensions, compatible with TFLN chip fabrication tolerances. We investigate impact of the inverse taper on the edge-coupling efficiency for various in-coupling optical beam dimensions as well as possible alignment tolerances and their spectral bandwidth. Our work will enable low-loss coupling into TFLN photonic integrated circuits paving the way for on-chip quantum photonics.

Q 40.22 Wed 17:00 Philo 1. OG

Simulating Surface Roughness Effects on TIR Coupling Losses in Thermally Annealed SLE Structures — •Thilo Danner, Veronica Montoya, Patrick Hildebrand, Yassin Nasr, Andreas Michalowski, and Tobias Menold — Institut für Strahlwerkzeuge (IFSW), Pfaffenwaldring 43, 70569 Stuttgart, Germany

Femtosecond laser-written structures in fused silica offer a versatile platform for integrated photonic devices, leveraging their 3D processing capabilities to enable integrated light handling, including guiding, reflecting, and focusing. Integrated light reflection is achieved via Selective Laser Etching (SLE) on a specific surface, where light is reflected through total internal reflection (TIR). Unfortunately, the SLE process inherently yields a rough surface, introducing scattering losses that degrade performance and cause unwanted mode distortion. Thermal annealing is a common method of reducing surface roughness. Using experimental roughness data, we simulated the influence of roughness after various annealing times to obtain the resulting coupling losses of a Gaussian beam into a waveguide. Various design parameters are simulated using electromagnetic solvers, specifically the Finite-Difference Time-Domain (FDTD) and Finite Difference Eigenmode (FDE) methods, to evaluate how much annealing is required to approach the surface quality demanded for low-loss coupling.

Q 40.23 Wed 17:00 Philo 1. OG

Simulation of light guiding and coupling in direct laser-written integrated optical elements — •Veronica Montoya, Thilo Danner, Patrick Hildebrand, Yassin Nasr, Andreas Michalowski, and Tobias Menold — Universität Stuttgart, Institut für Strahlwerkzeuge (IFSW), Pfaffenwaldring 43, 70569 Stuttgart

The trend to construct on-chip three-dimensional devices is growing, and direct laser-written structures (DLW) in glass represent a versatile key technology for integrated photonic systems. Major challenges lie in the currently insufficient theoretical understanding of the influence of the resulting refractive index profiles of DLW waveguides, as well as in the development of scalable and robust light coupling between a waveguide and other integrated optical element. Therefore, simulation-based preliminary work is essential. The goal of this project is to analyze and optimize the light-guiding behavior and coupling properties of DLW waveguides and coupling structures using simulation tools such as Ansys Lumerical. A realistic implementation of the refractive index profile resulting from DLW, along with the resulting mode structure, losses, and coupling functionality facilitated by Ansys' time, space, and frequency solutions, can provide the foundation for the targeted design of complex structures in the future.

Q 41: Poster – Quantum Technologies II & Laser Technology

Quantum Enabling Technologies; Laser Cooling and Trapping; Laser Technology and Applications

Time: Wednesday 17:00–19:00 Location: Philo 2. OG

Q 41.1 Wed 17:00 Philo 2. OG

Implementation of ground separation boards for DC and RF supply devices in trapped-ion experiments — •Jannik Mattil[1], Shobhit Saheb Dey[1], André Philipp Kulosa[1], Jonas Keller[1], Martin Ludwig Hesse[1,2], Ranjit Kumar Singh[1,2], Nicolas Spethmann[1], and Tanja Mehlstäubler[1,2] — [1]Physikalisch-Technische Bundesanstalt (PTB), 38116 Braunschweig, Germany — [2]Leibniz-Universität Hannover, 30167 Hannover, Welfengarten 1, Germany

Ion traps have matured into commercially available quantum technology products, used in high-precision applications such as optical clocks [1]. These applications demand highly sensitive spectroscopic measurements, making the suppression of perturbations essential. The trap control electronics can couple electro-magnetic noise into the trap electrodes. This electromagnetic field noise originating from inadequate grounding of electronic devices —ground loops— leads to increased motional heating and instability in precision measurements. We report about plug-and-play ground isolation boards designed to separate the DC and RF ground connections explicitly for usage of the Sinara hardware [2]. Three different isolation boards (capacitive, inductive, opto-coupled) have been designed and characterized to identify the best performance in noise suppression via heating rate measurements with trapped ions. [1] Jordan E., Brinkmann M., Didier A., Jansson E., Steinel M., Huntemann N., Shao H., Siebeneich H., Wunderlich C., Johanning M. und Mehlstäubler T. E., Quantum Sci. Technol. 10, 045005 (2025). [2] https://github.com/sinara-hw

Q 41.2 Wed 17:00 Philo 2. OG

Database for UHV and XUHV suitable materials for use in quantum technologies — •Vanessa Galbierz[1], Pascal Engelhardt[1,2], Sofia Herbers[1], and Piet Oliver Schmidt[1,2] — [1]Physikalisch-Technische Bundesanstalt, 38116 Braunschweig, Germany — [2]Leibniz Universität Hannover, Institut für Quantenoptik, 30167 Hannover, Germany

The background pressure of a vacuum system is one major limiting factor when it comes to the lifetime and coherence time of atomic quantum systems. Hence, potentially suitable materials for use in such experiments need to be assessed carefully regarding their outgassing behavior. To address this issue, we developed a strategy to identify, measure, and classify applicable materials, thereby assessing their suitability for use in UHV and XUHV environments. Identified materials, as well as subassemblies and commercially available parts, are then collected and indexed into a comprehensive database. We will present the prototype of this database in detail, including the outline structure and first results. We will demonstrate how standardization for the tabulation could work and which information is required to provide the data for even an inexperienced user, highlighting possible use cases and benefits for all types of vacuum-based experiments.

Q 41.3 Wed 17:00 Philo 2. OG

Sub-kHz, RF-traceable Frequency Comb with Dual-Domain Stabilization and Automated Locking — •Ali Seer, Jae-Ihn Kim, Florian Figge, Thomas Puppe, Christoph Stihler, and Matthias Scholz — TOPTICA Photonics SE, Gräfelfing, Germany

We present a dual-loop-stabilized DFG frequency comb providing simultaneous spectral purity and SI-traceable frequency accuracy. The scheme avoids the cost and complexity of high-finesse cavity-stabilized systems while delivering sub-kHz linewidths. A comb-comb comparison demonstrates an H-maser-like long-term stability limit. Fully automated locking and a unified GUI make the system a universal optical reference for quantum-optics experiments.

Q 41.4 Wed 17:00 Philo 2. OG

MEMS scanner mirrors for integration of an optical cavity in an ion trap — •Can Leichtweiss[1], Paul Raschdorf[2], Jan Müller[1], Jonas Vogel[1,3], Janine Hilder[1,3], Björn Lekitsch[1,3], Shanshan Gu-Stoppel[2], and Ferdinand Schmidt-Kaler[1,3] — [1]QUANTUM, Institut für Physik, 55128 Mainz — [2]Fraunhofer-Institut für Siliziumtechnologie, 25524 Itzehoe — [3]neQxt GmbH

The high fidelity readout of trapped ion qubits is based on the observation of laser-induced fluorescence. However, photons are randomly scattered in angle, which reduces the collection efficiency and increases the time required for readout. We plan to use the Purcell effect by deploying a resonant optical cavity such that photons are scattered into the cavity mode, which in turn could reduce the qubit detection time to a few μs.

We fabricate and test MEMS mirror devices, which allow for length stabilization and alignment of a high finesse cavity. We will position the cavity waist to the ion position without moving the ion itself, avoiding excess micromotion. Furthermore, a small footprint is required for an integration to an ion trap. We report results from a cavity with a ion-mirror distance of 0.8 mm, characterizing the finesse, waist size and adjustment features. In future, and with enhanced coupling [1], such cavity-enabled ion-light interface may allow for interconnecting trapped ion quantum processor modules.

[1] Takahashi, et al. *PRL* **124**, 013602 (2020)

Q 41.5 Wed 17:00 Philo 2. OG

Simulation-Based Approach for Programming a Spatial Light Modulator for Deterministic fs-Laser Writing of NV-Centers in Diamond — •Julian Staniewski[1], Lucas Kirchbach[1,2], Andreas Giese[2], Bernd Braun[2], and Andreas Stute[1,2] — [1]Faculty of Electrical Engineering, Precision Engineering, Information Technology, Technische Hochschule Nürnberg, Keßlerplatz 12, 90489 Nürnberg — [2]Faculty of Applied Mathematics, Physics and Humanities, Technische Hochschule Nürnberg, Keßlerplatz 12, 90489 Nürnberg

To generate deterministically placed vacancies in a diamond crystal, a high spatial-temporal energy density must be achieved in the crystal. Consequently, the wavefront of a fs-laser shall be corrected via a spatial light modulator (SLM) prior to entering the high numerical aperture focusing optics. This work presents an optical model that allows for calculating the phase mask to be imposed by the SLM. To validate the accuracy of the model, crystal samples of different thickness are used in a test setup to intentionally introduce aberrations. The model is verified via comparing such wavefront measurements with the model predictions.

Q 41.6 Wed 17:00 Philo 2. OG

Highly-efficient, low noise quantum frequency conversion of single photons from a tin-vacancy center in diamond — •Marlon Schäfer, David Lindler, Tobias Bauer, and Christoph Becher — Universität des Saarlandes, Campus E2 6, 66123 Saarbrücken

Quantum frequency conversion (QFC) is a key enabling technology for quantum repeaters and large-scale quantum networks, as it connects quantum memories with optical transitions in the visible and near-infrared spectrum to the low-loss telecommunication bands used in optical fiber networks. Here, we demonstrate a highly efficient and low-noise QFC device for single photons resonant with tin-vacancy (SnV) centers in diamond. Using difference-frequency generation in periodically poled lithium niobate waveguides, single photons at 619 nm are mixed with a strong 2062 nm pump beam to generate light at an intermediate wavelength of 885 nm, followed by a second conversion stage to 1550 nm. This two-step conversion scheme strongly suppresses noise from pump-induced spontaneous parametric processes as well as Raman scattering, resulting in an exceptionally low noise level of less than 4 photons per second per gigahertz of filter bandwidth. In addition, the device achieves a fiber-to-fiber conversion efficiency of 45%, including an 8 GHz bandwidth filtering stage. Measurements of second-order correlation functions for the converted photons confirm the preservation of nonclassical photon statistics after frequency conversion.

Q 41.7 Wed 17:00 Philo 2. OG

Comparison of High-Precision PM-Fiber Alignment Methods for Integrated Photonic Devices — •Philipp Will[1], Lucas Kirchbach[1,2], Alexander Bachmann[3], Rainer Engelbrecht[1,3], and Andreas Stute[1,2] — [1]Technische Hochschule Nürnberg, faculty efi, Nuremberg, Germany — [2]Technische Hochschule Nürnberg, faculty amp, Nuremberg, Germany — [3]Technische Hochschule Nürnberg, Polymere Optical Fiber Application Center (POF-AC), Nuremberg, Germany

This work compares three experimental methods for determining the rotation angle and position of polarization-maintaining fibers for use in integrated fiber arrays: detection of the front-face panda structure, polarization measurements of the light guided by the fiber, and imaging the panda structures via the lateral view of the fiber. Position and rotational angle of the PM fiber are detected via image recognition algorithms. Achieved positional accuracies lie in the sub-micrometer range, rotational accuracies in the range of 0.01 rad corresponding to a polarization extinction ratio of > 40 dB.

Q 41.8 Wed 17:00 Philo 2. OG

Characterization of photonic qubit conversion from polarization to time-bin in the telecom range — •Julian Gross-Funk[1,2], Christian Haen[1], and Jürgen Eschner[1] — [1]Universität des Saarlandes, Experimentalphysik, 66123 Saarbrücken, Germany — [2]see below

Many photonic quantum memory implementations rely on the time-bin degree of freedom, which protects against decoherence in fiber transmission, in contrast to polarization encoding. Time-bin qubits, however, lack compatibility with photonic polarization qubit implementations, such as single photons emitted by single trapped ions [1].

In this poster, we present a fiber-based converter for photonic 1550 nm polarization qubits to the time-bin degree of freedom, enabling quantum experiments between different platforms. The fundamental setup is based on an unbalanced interferometer for conversion and a second one for measurement and reconstruction of the converted states. The 18 m imbalance of the interferometer arms induces a sensitivity to temperature variations in the millikelvin range, that we compensate by an active temperature and phase stabilization scheme based on a reference laser beam.

We investigate the influence of the temperature on the reconstruction fidelity, characterize the device by its ability to preserve the quantum information and evaluate its performance with regard to other applications.

[1] M. Bock et al., Nature Commun. 9, 1998 (2018).

[2]presently at German Aerospace Center (DLR), Institute of Quantum Technologies, 89081 Ulm, Germany

Q 41.9 Wed 17:00 Philo 2. OG

Cryogenic integrated circuits for scalable trapped-ion based quantum computers — •Sebastian Halama[1], Marco Bonkowski[1], Peter Toth[2], Alexander Meyer[2], Marius Neumann[3], Vadim Issakov[2], and Christian Ospelkaus[1,4] — [1]Institut für Quantenoptik, Leibniz Universität Hannover, Welfengarten 1, 30167 Hannover, Germany — [2]Institut für CMOS Design, Technische Universität Braunschweig, Hans-Sommer-Straße 66, 38106 Braunschweig, Germany — [3]Institut für Elektrische Messtechnik und Grundlagen der Elektrotechnik, Technische Universität Braunschweig, Hans-Sommer-Straße 66, 38106 Braunschweig, Germany — [4]Physikalisch-Technische Bundesanstalt, Bundesallee 100, 38116 Braunschweig

State of the art quantum computers are still too small and have a too high error rate to tackle any useful problem. Surface-electrode ion traps are a promising platform to overcome both issues. However, with increased size the number of required electrical signal grows. Specially for cryogenic vacuum chambers, this will eventually result in a non tolerable heat load originating from cables. A possible solution is to hybrid-integrate control electronics together with the ion trap [1, 2]. This can potentially reduce the number of externally applied control signals to only a few, while it is still possible to supply hundreds of electrodes with suitable voltages. We present our latest work on integrating DC and microwave generators with a cryogenic ion trap.

[1] A. Meyer et al., DOI: 10.1109/TIM.2025.3571087
[2] P. Toth et al., DOI: 10.1109/ISSCC49661.2025.10904696

Q 41.10 Wed 17:00 Philo 2. OG

Sub-natural linewidth absorption filter based on Raman resonance in hot atomic vapour — •Viola-Antonella Zeilberger[1], Inna Kviatkovsky[1], Lucas Pache[1], Leonid Yatsenko[2], Philipp Schneeweiss[1], Jürgen Volz[1], and Arno Rauschenbeutel[1] — [1]Institute of Physics, Humboldt University of Berlin, Berlin, Germany — [2]Institute of Physics, National Academy of Sciences of Ukraine, Kyiv, Ukraine

Narrow optical band-stop filters are essential for fundamental research and a wide range of photonic technologies, including quantum memory and low-frequency Raman spectroscopy. Experimentally, narrow absorption features are realised using optical resonators or Faraday filters. In this work, we present an experimental realisation of a subnatural linewidth filter based on Raman resonance in hot ^{87}Rb vapour. The filter builds on a three-level lambda scheme on the D1 line, where two optical fields couple the hyperfine ground states to a common excited state. By driving Raman transitions at single-photon detunings larger than the Doppler width of the atomic vapour, we are able to obtain absorption features in the kilohertz regime, well below the natural linewidth. We further investigate the influence of buffer gas and the addition of a repump field for achieving higher optical depth. This implementation of an optical notch-filter combines the advantages of a spectral narrow-band absorption window with high off-resonant transmission and thus can be crucial for applications where narrow spectral features have to be attenuated without affecting the rest of the spectrum.

Q 41.11 Wed 17:00 Philo 2. OG

Zerodur-Based Compact Laser and Vacuum Systems — •Bojan Hansen[1], Nora Bidzinski[1], Robin Lelewel[1], Takeshi Matsuyama[1], David Latorre Bastidas[2], André Wenzlawski[2], Patrick Windpassinger[2], Ortwin Hellmig[1], and Klaus Sengstock[1] — [1]Institute for Quantum Physics, University of Hamburg, Germany — [2]Institut für Physik, Johannes Gutenberg-Universität Mainz, Germany

Adapting ultra cold atom experiments for portable applications demands strict constraints on size, energy consumption, and environmental resilience. We present a compact, energy-efficient Zerodur-based MOT laser system that employs optical cavities as frequency references not only for fast frequency switching but also for stabilising the cooling and repumping lasers against a laser with an atomic reference. This approach significantly reduces system footprint, enhances energy efficiency, and introduces redundancy and autonomy. Complementing this, we develop a flange-free, ultra-portable Zerodur vacuum chamber operating without an active getter pump. Together, these innovations advance the realisation of robust, compact, and portable quantum devices, potentially fitting within a shoebox-sized form factor.

Q 41.12 Wed 17:00 Philo 2. OG

Packaging of All-Laser-manufactured Vapor-cell for Interposer integrated Quantum sensing — •Patrick Hildebrand, Yassin Nasr, Veronica Montoya, Thilo Danner, Andreas Michalowski, and Tobias Menold — University of Stuttgart, Institut für Strahlwerkzeuge (IFSW), Stuttgart, Germany

This work presents a concept for a fully laser-fabricated, photonic-integrated vapor cell intended for compact quantum sensors such as chip-scale magnetometers and gyroscopes. The approach combines femtosecond direct writing for waveguide formation with Selective Laser Etching (SLE) to create the vapor-cell cavity and internal micro-optics. Elements such as micromirrors and integrated miniature lenses are designed to reduce coupling losses between the waveguides and the vapor cell as well as to a flip-bonded laser diode and photodiode. Laser-based bonding is proposed for hermetic sealing without mechanical alignment or additional materials.

Compared with conventional MEMS vapor cells relying on free-space optics, this glass-based architecture embeds all optical paths directly into the substrate, eliminating external alignment components and reducing sensitivity to vibration and temperature variations. Combining waveguide writing, cavity formation, micro-optics fabrication, and bonding into a single laser-based process chain is expected to simplify assembly and improve reproducibility. The concept outlines a path toward integrated vapor-cell modules that are robust, compact, and scalable for industrial production.

Q 41.13 Wed 17:00 Philo 2. OG

Towards time-reversing an exponentially rising pulse with a single ground state cooled ^{174}Yb$^+$ ion — •Sebastian Luff[1,2], Hans Dang[1,2], Martin Fischer[1], Markus Sondermann[1,2], and Gerd Leuchs[1,2] — [1]Max Planck Institute for the Science of Light, Erlangen, Germany — [2]Friedrich-Alexander-Universität Erlangen-Nürnberg, Erlangen, Germany

Deterministic excitation of a single ion by a single photon can be realized when the temporal envelope of the photon matches the time-reversed waveform of a spontaneously emitted photon from the same atomic transition [1]. In this work, we implement such a scheme by sending an exponentially rising pulse onto a ^{174}Yb$^+$ ion, driving its strong dipole transition (370 nm wavelength, 8.1 ns life time). To enhance the photon-ion coupling efficiency, the ion is positioned inside a deep parabolic mirror that covers nearly the full solid angle of the incident light field [2]. This geometry enables near-maximal spatial mode overlap between an incident doughnut-shaped mode and the ion's dipole radiation pattern. Furthermore, the ion is cooled well below the Doppler limit through resolved sideband cooling, reducing its spatial extent to a size smaller than the focal spot of the parabolic mirror. We report on our progress towards achieving the maximum coupling possible with this system.

1. Leuchs, G. & Sondermann, M. Phys. Scr. 85, 058101 (2012).
2. Maiwald, R. et al., Phys. Rev. A 86, 043431 (2012).

Q 41.14 Wed 17:00 Philo 2. OG

Parallel cryogenic setups for scalable quantum computation with surface ion traps — •Marco Schmauser[1], Marco Valentini[1], Eric Kopp[1], Michael Pasquini[1], Jakob Wahl[1], Andreas Wendl[2], Philip Holz[3], Josef Schupp[3], Philipp Schindler[1], Thomas Monz[1,3], and Rainer Blatt[1] — [1]Inistitut für Experimentalphysik, Universität Innsbruck, Austria — [2]kiutra, Munich, Germany — [3]Alpine Quantum Technologies, Innsbruck, Austria

Trapped-ion (TI) quantum systems are promising candidates for future quantum computing applications. TI devices based on macroscopic linear Paul traps are practically limited to a maximum of 30 ions. Microfabricated surface traps are an alternative approach that allow for improved scalability though modular design, integrated optics, and additional electronic trap layers.

Here we present the implementation of parallel cryogenic setups, one rack-based, and one table-based for rapid testing and characterization of such surface traps. Each setup features an independent cryostat able to cool to a base temperature of 5K within 12 hours. Trap integration is realized via a standardized socket interface, reducing trap exchange time to approximately 2 hours. The setups feature 128 (100) DC electrodes, 6 RF electrodes, 21 in-vacuum fibers for 40Ca+ wavelengths, and two independent resonators to enable concurrent axial and radial shuttling. The rack-based setup additionally features a novel hermetic interface to facilitate rapid swapping of vacuum chambers without venting, thus minimizing experimental downtime.

Q 41.15 Wed 17:00 Philo 2. OG

Quantum characterization and control of single molecules — •Max Koppelstätter — Universität Innsbruck, Innsbruck, Austria

The QCosmo team studies quantum states and dynamics in trapped polyatomic molecular ions with quantum logic spectroscopy (QLS). This method maps molecular transitions to a co-trapped atomic logic ion, enabling robust and efficient state readout. We focus on novel spectroscopy techniques, rovibronic state preparation and control, and the possibilities and limitations of applying quantum information processing techniques to molecular ions. We have recently measured the infrared vibrational transition frequency in the OH stretch mode of a single trapped $CaOH^+$ molecular ion using cat state recoil spectroscopy. This method uses cat states to amplify the detection of the recoil of a single absorbed photon via an accumulated geometric phase. We are also developing Raman QLS to enable molecular hyperfine and rotational spectroscopy and control. Ongoing work includes planning and development of a second-generation cryogenic experiment with a segmented ion trap. The segmented design enables axial control for optimal ion positioning, while the cryogenic environment suppresses quantum jumps from thermal radiation and background gas collisions, extending ion storage and coherence times. Another component currently under development is the ion-injection system, which introduces molecular ions into the cryogenic environment.

Q 41.16 Wed 17:00 Philo 2. OG

A laser system for cooling 87Rb atoms in an optical cavity — •Daniel Reigel, Luis Weiss, Sebastián Alejandro Moralez Ramirez, Raphael Benz, Micha Kappel, Maurizio Trigilia, Vincent Beguin, Leon Layer, Violet Ruf, and Stephan Welte for the QNN-Collaboration — 5. Physikalisches Institut, Center for Integrated Quantum Science and Technology and CZS Center QPhoton, Universität Stuttgart, Pfaffenwaldring 57, 70569 Stuttgart, Germany

Arrays of neutral atoms at the center of an optical cavity are a promising platform for implementing quantum-coherent network nodes, which can be interconnected using flying optical photons. To prepare such a system, laser-cooling techniques are required to cool the atoms, such that they can be trapped in optical potentials. We present our laser setup for cooling neutral 87Rb atoms in a magneto-optical trap (MOT). This serves as a source of cold atoms for the planned experiments. Our cooling laser is locked to an ultra-low-expansion (ULE) cavity. We describe our locking scheme as well as the subsequent acousto-optic modulators used to tune the lasers to the respective cooling transitions. We also present the development and implementation of a two-dimensional MOT that relies on the laser system described above. In the planned experiments, we aim to generate an intra-cavity atom-tweezer array with individual-atom addressing. We designed a 2D MOT in a glass cell attached to the main chamber. We discuss the design of the components of this MOT, and the mechanical mounting of our dispensers in the glass cell. Finally, we provide an outlook on the planned experiments with the new quantum-network setup.

Q 41.17 Wed 17:00 Philo 2. OG

Atomic Dynamics in Time-Dependent Optical Dipole Traps using GPU Computing — •Paul Christ and Reinhold Walser — Institut für Angewandte Physik, TU Darmstadt, Hochschulstraße 4A, 64289, Darmstadt

We investigate the classical non-equilibrium dynamics of neutral ^{87}Rb atoms confined in optical dipole traps. Motivated by experiments in the group of Prof. Birkl at TU Darmstadt [1,2], our work focuses on a crossed-beam dimple trap geometry, where a deep, tightly confining potential minimum at the beam intersection is used to enhance phase-space density. This will lead to the reversible creation of a Bose-Einstein condensate (BEC).

To optimize the evaporative cooling, we implement time-dependent potentials that accurately describe the dynamic lowering of the trap depth. The project utilizes classical molecular dynamics (MD) simulations using Graphics Processing Units (GPUs). The evaluation of the binary forces acting on a particle benefits significantly from the massive parallelization. To ensure long-term numerical stability and energy conservation, we employ and compare higher-order symplectic integration algorithms.

From the MD simulation, we find the relaxation dynamics (collision rates, scaling laws and thermodynamic relations) of the gas and obtain the critical experimental parameters.

[1] D. Pfeiffer, Dissertation TU Darmstadt, 10.26083/tuprints-00031145, (07/2025)
[2] T. Lauber et al., Phys. Rev. A **84**, 043641 (2011)

Q 41.18 Wed 17:00 Philo 2. OG

Pulsed UV Laser System for Laser Cooling of Relativistic Bunched Ion Beams — •Harri Lara[1], Tamina Grunwitz[1,2], Benedikt Langfeld[1,2], and Thomas Walther[1,2] — [1]TU Darmstadt — [2]HFHF Campus Darmstadt

At FAIR's synchrotron SIS100, laser cooling is the planned method for narrowing the momentum distribution of relativistic bunched ion beams. Due to the specific demands of the SIS100, three lasers will be used: Two pulsed lasers for pre-cooling that can address ions over a wide range of velocity classes due to their spectral width and one continuous wave laser to further cool the ions to the coldest temperatures.

In this contribution, we present our pulsed UV laser system with a centre wavelength of 257 nm. For the purposes of laser cooling application, the UV pulsed system produces pulses between 46 and 734 ps with a repetition rate between 1 and 10 MHz. Additionally, an average power output of 5.3 W has been achieved at 257 nm. Since the construction of this pulsed laser system, we have begun to duplicate it for use at the SIS100 and we will also present the progress made on the development of this duplicated system.

Q 41.19 Wed 17:00 Philo 2. OG

Towards ground state cooling of ^{115}In$^+$ – ^{172}Yb$^+$ Coulomb crystals — •Mouhamed-Omar Manai[1,2], Ingrid M. Richter[1], H. Nimrod Hausser[1], Shobhit S. Dey[1], Dongliang Cong[1], Jonas Keller[1], and Tanja E. Mehlstäubler[1,2] — [1]Physikalisch-Technische Bundesanstalt, Braunschweig, Germany — [2]Leibniz Universität Hannover, Hanover, Germany

One of the major contributions to the error budget of state-of-the-art optical clocks is second-order Doppler shift, also referred to as time dilation (TD) shift. Ground-state (GS) cooling of the clock ions not only suppresses this TD shift as well as line broadening beyond what is achievable with Doppler cooling alone, but also allows for the manipulation of the motional state by single quanta.

Our multi-ion clock features a mixed-species Coulomb crystal trapped in a radiofrequency Paul trap [1]. Clock campaigns have been conducted with up to eight ^{115}In$^+$ clock ions, which are sympathetically cooled by twelve ^{172}Yb$^+$ ions. The systematic uncertainty in this configuration is at the 1×10^{-18} level, with TD shift being one of the limiting contributions.

We are currently implementing GS cooling on the $^1S_0 \rightarrow {}^3P_1$ intercombination transition of In^+, in an intermediate regime with a linewidth of $\gamma = 360\,\text{kHz}$. This will allow for spectroscopic investigations of the TD shift, in turn allowing us to further reduce our clock uncertainty, along with tests of relativity.

[1] H. N. Hausser et al., Phys. Rev. Lett. 134, 023201 (2025)

Q 41.20 Wed 17:00 Philo 2. OG

Rotational state preparation of $CaOH^+$ — •Miriam Kautzky, Brandon Furey, Zhenlin Wu, Mariano Isaza-Monsalve, Tim Duka, Max Koppelstätter, and Philipp Schindler — Institut für Experimentalphysik, Universität Innsbruck, Austria

Molecules possess complex degrees of freedom not available in atoms, making them excellent systems for testing fundamental physics through spectroscopy of their internal structure. Their quantum mechanical rotation is a potential resource for quantum technologies and enables quantum error correction (QEC) codes that protect against spontaneous decay. Preparing molecules in pure rotational states is essential for implementing such codes and for spectroscopic methods relying on quantum logic. We aim to cool molecules to low rotational levels and prepare specific rotational levels with Raman interactions. We are developing an experimental setup to achieve rotational level cooling and level preparation of $CaOH^+$ ions with spectrally shaped broadband laser pulses on a vibrational transition. Spectral shaping enables rotational cooling by driving only specific rovibrational transition bands and thus allowing selective population transfer. It requires precise control of the laser spectrum to target only P-branch transitions. While rotational ground-state cooling has previously been demonstrated, precise control over rotational states, particularly in polyatomic molecules, remains less explored. Achieving this control could enable exploration of quantum information processing and QEC with trapped molecular ions.

Q 41.21 Wed 17:00 Philo 2. OG

KOAQS – novel design for compact cold-atom sources — •Constantin Avvacumov, Alexander Herbst, Wei Liu, Ashwin Rajagopalan, Knut Stolzenberg, Daida Thomas, Ernst M. Rasel, and Dennis Schlippert — Leibniz Universität Hannover, Institut für Quantenoptik

Atom interferometers are powerful instruments for fundamental research and geodesy, including applications such as gravimetry. Quantum projection noise and the demand for high sampling rates motivate the development of new high-flux sources of cold atoms. The typical first atom cooling stage of atom interferometers is a two-dimensional magneto-optical trap (2D-MOT). Recent efforts to reduce the SWaP (size, weight and power) of 2D-MOTs have raised questions about the feasibility of integrating optics more closely into the vacuum chamber and the long-term compatibility of high-reflectivity optical coatings exposed to alkali vapor such as potassium or rubidium.

In this poster, we present KOAQS (Kompakte Atomquelle für Quantensensoren) – a novel high-flux 2D-MOT design with improved SWaP characteristics. To ensure long-term performance, we conduct a systematic analysis of the interaction between Rb vapor and various highly reflective coating materials using accelerated aging tests. The best-performing mirror type is implemented in our 2D-MOT, and we present its functionality and characterization of its performance.

Q 41.22 Wed 17:00 Philo 2. OG

Optimierung des Kopplungslasers zur Vorbereitung auf LWI im UV-Bereich — •Tobias Neumann, Thorsten Führer und Thomas Walther — TU Darmstadt

Lasing without Inversion (LWI) stellt einen vielversprechenden Ansatz zur Erzeugung kohärenter Strahlung im UV- und VUV-Bereich dar, wobei auf die hohen Pumpintensitäten konventioneller Laserquellen verzichtet werden kann. Frühere Arbeiten im Quecksilber-Vier-Niveau-System identifizierten dabei entscheidende Parameter für Amplification without Inversion (AWI)[1]. Um diese zu erreichen, ist insbesondere eine höhere Leistung des Kopplungslasers bei 435,8 nm erforderlich. Aus diesem Grund wird derzeit ein umfassender Neuaufbau dieses Lasersystems umgesetzt. Gemäß dem neuen Konzept ist eine vollständige Entkopplung der Regelkreise für Frequenzstabilisierung und Frequenzverdopplung vorgesehen. Die für die Frequenzstabilisierung erforderliche 435,8-nm-Strahlung wird durch Single-Pass-Frequenzkonversion erzeugt, während die für das AWI-Experiment relevante Verdopplung in einem Überhöhungsresonator stattfindet. Darüber hinaus werden Steuerungs- und Elektronikhardware modernisiert, um die Stabilität und Langzeitzuverlässigkeit zu erhöhen. Die Implementierung dieser Maßnahmen zielt darauf ab, die Rahmenbedingungen für zukünftige AWI- und LWI-Messungen im UV-Bereich zu ermöglichen. Es werden erste Ergebnisse des neu aufgebauten Lasersystems sowie der nächsten experimentellen Schritte präsentiert.

[1] Daniel Preißler (2024) doi.org/10.26083/tuprints-00027578

Q 41.23 Wed 17:00 Philo 2. OG

Continuous Wave UV Laser System for Cooling Relativistic Bunched Ions — •Denise Schwarz[1], Jens Gumm[1], and Thomas Walther[1,2] — [1]Technische Universität Darmstadt — [2]HFHF Darmstadt

Bunched relativistic ion beams with a narrow momentum distribution are essential for precision experiments at modern accelerator facilities. Laser cooling presents a promising approach to further reduce the relative momentum distribution of such ion beams.

This work presents the high power UV cw laser system for laser cooling at the SIS100 at FAIR. The laser system can be scanned without experiencing mode-hops over 25 GHz in the infrared. In two cavities, frequency conversion is employed to achieve the necessary wavelength of 257 nm for laser cooling. The second enhancement cavity employs an elliptical focus to avoid degradation of the BBO crystal while achieving a high an stable output in the UV.

Q 41.24 Wed 17:00 Philo 2. OG

Laser frequency noise measurement close to the shot noise limit — •Christoph Raab[1], Jonas Vogel[3], Björn Lekitsch[3], and Ferdinand Schmidt-Kaler[2,3] — [1]Hochschule Darmstadt, Darmstadt, Germany — [2]QUANTUM, Universität Mainz, Mainz, Germany — [3]neQxt GmbH, Erlenbach, Germany

Frequency-stabilized laser sources are used in many industrial or scientific applications like spectroscopy, frequency standard, interferometry and quantum technology. Typically, the freqency noise of a source is characterized by a beat note with a second laser. Here, we present a measurement setup to precisly characterise the frequency and phase noise of a cw laser without this significant overhead. The setup employes an interferometric approach to convert frequency fluctuations into an amplitude signal, detected by a photo diode. We find that the noise limit of the interferometer is dominated by the detection noise. Therefore, we carefully select and optimize the photodetector and the digitizing system, reaching a lower limit for the frequency noise density of a few Hz^2/Hz or an equivalent laser linewidth of about 10 Hz. Our setup is optimzed for laser sources in the wavelength range of 620 nm to 870 nm, but the setup can be adapted over the entire range of visible to IR wavelengths.

Q 41.25 Wed 17:00 Philo 2. OG

Active Feedback for relative intensity noise reduction in solid-state lasers — •Thomas Konrad[1], Tobias Steinle[1], Roman Bek[2], Michael Scharwaechter[2], Matthias Seibold[2], Andy Steinmann[1], and Harald Giessen[1] — [1]4th Physics Institute and Research Center SCoPE, University of Stuttgart — [2]Twenty-One Semiconductors GmbH, Stuttgart

Fast and precise measurements are key for many challenging laser applications, such as biological and biomedical imaging. The precision is limited by the noise of the systems we use. Once the measurement precision reaches the laser noise level, the measurement time must be increased quadratically for further improvement. Especially with biological samples, a significant longer measurement time can alter the specimen and/or results. Therefore, exploiting the optimum noise characteristic of the driving source is superior to increasing measurement time. In this work, we investigate noise reduction of a solid-state laser in the spectroscopically relevant 1 kHz - 10 MHz frequency range. Our approach differs from traditional subsequent noise eaters, since we reduce the noise within the laser oscillator itself. In contrast to comparable commercial solutions with monolithic crystal oscillators, we use a free space cavity with two gain materials. To compensate the noise of our laser, we use a second high-speed gain medium in the cavity whose pump is modulated by a PID feedback loop, while the main medium remains constantly pumped. So far, we achieved a noise reduction of more than 18 dBc/Hz at the relaxation oscillation frequency.

Q 41.26 Wed 17:00 Philo 2. OG

Development of cw laser systems in the deep-UV and vacuum-UV ranges — •Jonas Gottschalk[1], Lukas Möller[1], Björn-Benny Bauer[1], Felix Waldherr[1], Sascha Haider[1], Thorsten Groh[1], Stephan Hannig[2], Stefan Truppe[3], Sid Wright[4], Simon Stellmer[1], and UVQuanT Consortium[1] — [1]Universität Bonn, Germany — [2]Agile Optics GmbH — [3]Imperial

College London — [4]Fritz Haber Institute of the Max Planck Society

Reliable and tunable ultraviolet (UV) laser sources are increasingly important for applications in spectroscopy and precision metrology, yet many UV wavelengths remain difficult to access efficiently.

We present a set of UV laser systems that employ cascaded sum-frequency-generation (SFG) stages in nonlinear crystals using different phase matching schemes.

The fundamental light is provided by Diode, VECSEL and Ti:Sa lasers.

The SFG stages are implemented in both single-pass and cavity-enhanced configurations, including one system employing an elliptical cavity mode.

The resulting systems deliver stable, narrowband radiation across multiple regions of the UV spectrum, from 185 nm to 310 nm, demonstrating a versatile and scalable platform for advanced UV laser generation.

Q 41.27 Wed 17:00 Philo 2. OG

Automated Calibration of a MZI-Mesh based Optical Computer — •Okan Akyüz[1], Konrad Tschernig[1], Mingwei Yang[1,2], Felix Kübler[1], Lennart Mannteuffel[1], Enrico Stoll[1], and Janik Wolters[1,2] — [1]Technische Universität Berlin, Berlin, Germany — [2]Deutsches Zentrum für Luft- und Raumfahrt, Institut für Weltraumforschung, Berlin, Germany

Optical computing uses light instead of electronic signals for computation, with hardware such as Mach-Zehnder-interferometer (MZI)-based systems that implement programmable linear optical networks. A major challenge is individually calibrating each unique phase shifter for applications ranging from Vector-Matrix Multiplication (VMM)[1] to quantum computation[2]. In this work, we demonstrate the automated calibration of a 12x12-mode MZI-mesh based optical processor. We use external optical switches to feed a laser into input ports and measure the output intensity from the corresponding output ports. A tailored algorithm allows isolating the effect of each of the 132 phase shifters and determining the heating power to phase calibration. After isolating each phase shifter, we can perform a voltage sweep to determine the voltage-to-phase calibration curve. We give an outlook on how this calibration can be used to realize efficient optical VMM in machine learning problems.

[1] Shen, Y., et al. Deep learning with coherent nanophotonic circuits. Nature Photon 11, 441-446 (2017).

[2] Sergei Slussarenko, et al.; Photonic quantum information processing: A concise review. Appl. Phys. Rev. 1 December 2019.

Q 41.28 Wed 17:00 Philo 2. OG

Progress of the BECCAL Laser System for Cold Atom Experiments onboard the ISS — •Hamish Beck[1], Hrudya Thaivalappil Sunilkumar[1], Marc Kitzmann[1], Christoph Weise[1], Bastian Leykauf[1], Evgeny Kovalchuk[1], John Davenport[1], Jakob Pohl[1], Achim Peters[1], and the BECCAL Collaboration[1,2,3,4,5,6,7,8,9,10] — [1]HUB, Berlin — [2]FBH, Berlin — [3]JGU, Mainz — [4]LUH, Hanover — [5]DLR-SI, Hanover — [6]DLR-QT, Ulm — [7]UULM, Ulm — [8]ZARM, Bremen — [9]DLR, Bremen — [10]DLR-SC, Braunschweig

The Bose-Einstein Condensate and Cold Atom Laboratory (BECCAL) is designed for operation onboard the International Space Station (ISS). This multi-user facility will enable experiments with Rb and K ultra-cold atoms and BECs in mircogravity. Fundamental physics will be explored at longer time- and lower energy-scales compared to those achieved on earth.

The BECCAL laser system is comprised of micro-integrated diode lasers, miniaturized free-space optics on Zerodur boards, and a system of fibres to bring light to the physics package. The design is subject to strict size, weight, and power (SWaP) constraints, and the operation of the system is supported by extensive ground-based systems.

The ground-based systems built for validation and testing will be presented alongside the design of the flight model.

This work is supported by the DLR with funds provided by the BMWK under grant number 50WP2102.

Q 42: Poster – Ultracold Matter (joint session Q/A)

Bosons; Fermions; Rydberg Systems; Experimental Methods

Time: Wednesday 17:00–19:00 Location: Philo 2. OG

Q 42.1 Wed 17:00 Philo 2. OG

Pattern coarsening in dipolar quantum gases — •Andreea-Maria Oros[1], Wyatt Kirkby[1,2], Lauriane Chomaz[2], and Thomas Gasenzer[1,3] — [1]Kirchhoff-Institut für Physik, Universität Heidelberg, Im Neuenheimer Feld 227 — [2]Physikalisches Institut, Universität Heidelberg, Im Neuenheimer Feld 226 — [3]Institut für Theoretische Physik, Universität Heidelberg, Philosophenweg 16

Ultracold dipolar gases have garnered increasing interest over the past years. The anisotropic and long-range character of the dipolar interaction and the stabilizing nature of the LHY correction give rise to supersolidity, superglasses, and exotic states of matter. Depending on the atom number, scattering length, and trapping geometry, different supersolid morphologies, such as triangular, honeycomb, and labyrinthine, have already been theoretically predicted to be the possible ground states of such a system. Our work expands on these phases by considering the out-of-equilibrium dynamics of a three-dimensional dipolar condensate, trapped only along the polarisation direction. Therein, we aim to bridge the theory of supersolid dipolar condensates to that of phase transitions present in melting dynamics. Furthermore, we investigate the crystalline properties across the superfluid-supersolid transition by extending procedures employed in Kosterlitz-Thouless-Halperin-Nelson-Young theories, and as a result observe coarsening behaviour in the local orientation.

Q 42.2 Wed 17:00 Philo 2. OG

Stability analysis of a holographic superfluid — •Martin Zboron[1], Gregor Bals[2,3], Carlo Ewerz[2,3], and Thomas Gasenzer[1,2,3] — [1]Kirchhoff-Institut für Physik, Univ. Heidelberg, Im Neuenheimer Feld 227, 69120 Heidelberg — [2]Institut für Theoretische Physik, Univ. Heidelberg, Philosophenweg 16, 69120 Heidelberg — [3]ExtreMe Matter Institute EMMI, GSI Helmholtzzentrum für Schwerionenforschung, Planckstraße 1, 64291 Darmstadt, Germany

Gauge-gravity duality establishes a connection between strongly correlated quantum systems and higher-dimensional gravitational theories at weak coupling. Utilising an Abelian Higgs model in an asymptotically anti-de Sitter spacetime, one obtains the so-called holographic s-wave superfluid. Due to Bekenstein-Hawking entropy, a black brane provides a finite temperature to this system. Allowing particles and energy to fall behind the horizon relates to a strong dissipation in the superfluid. A Bogoliubov-type analysis of small excitations in the bulk reveals their dispersion relation as well as their damping rates, granting insights into the relevant dissipation mechanisms. Numerical results of this analysis enable comparisons of the holographic superfluid to phenomenological models of finite-temperature superfluids, such as the dissipative Gross-Pitaevskii equation, as well as experimentally realised superfluids.

Q 42.3 Wed 17:00 Philo 2. OG

Universal scaling and emergent symmetries in a spin-1 Bose gas far from equilibrium — •Ido Siovitz, Anna-Maria E. Glück, Yannick Deller, Helmut Strobel, Markus K. Oberthaler, and Thomas Gasenzer — Kirchhoff Institute for Physics, Universität Heidelberg

Quantum many-body systems driven far from equilibrium can show universal self-similar scaling dynamics associated with an approach to a non-thermal fixed point. The characterisation of non-equilibrium universality classes remains an open problem. Here we show the thorough investigation of non-equilibrium universality using the spin-1 Bose gas as a platform. We identify rogue waves in the velocity fields of the single components, leading to real-time instantons in the transverse spin degree of freedom. We derive a low-energy effective field theory of the spin-1 gas, taking the form of a double sine-Gordon model for the spinor phase. This model accounts for the subdiffusive and diffusion-type scaling observed in the full microscopic theory. We show Numerical as well as experimental results that support the validity of the effective model. Lastly, we demonstrate that different quenches can lead to two distinct non-thermal fixed points, each associated with a different emergent symmetry signaled by symmetry witnesses derived from Ward identities.

Q 42.4 Wed 17:00 Philo 2. OG

Universal dynamics of 3D Bose gases near the superfluid transition in the collective-scattering regime — •Anne-Solène Bornens, Elisabeth Gliott, and Nicolas Cherroret — Laboratoire Kastler-Brossel, Sorbonne Université, CNRS, ENS-PSL, Collège de France, Paris, France

Understanding the many-body dynamics of a quantum system after a quench is a central challenge in modern physics. In particular, quantum gases quenched across a phase transition display especially intriguing dynamics, as they generically evolve toward a nonthermal fixed point, i.e. a self-similar evolution of correlations with universal dynamical exponents and a critical slowing down. Recently observed experimentally, this phenomenon compellingly extends the notion of universality classes to nonequilibrium statistical physics.

In this work, we theoretically investigate the universal many-body dynamics of three-dimensional Bose gases suddenly cooled across their superfluid phase transition. Using a quantum kinetic framework that captures the collective-scattering regime emerging in the highly occupied part of the spectrum, we uncover a crossover between two dynamical universality classes controlled by the quench depth. For weak quenches, we find early-time inverse and direct energy cascades characteristic of weak turbulence, where collective scattering plays little role. For deep quenches, collective scattering dominates and a turbulent fixed point emerges, marked by modified dynamical exponents, a more pronounced bidirectional cascade, and an overall slowing down of the dynamics.

Q 42.5 Wed 17:00 Philo 2. OG

The Slox Trap: Absorptive Boundaries for Infinitely Extended Physics — •Nikolas Liebster[1,2], Jelte Duchene[1], Elinor Kath[1], Hanyi Jang[1], Helmut Strobel[1], and Markus Oberthaler[1] — [1]Kirchhoff-Institut für Physik, Universität Heidelberg, Im Neuenheimer Feld 227, 69120, Germany — [2]Department of Physics, Ludwig-Maximilians-Universität München, Schellingstr. 4, 80799 Munich, Germany

A common impediment to the comparison between theoretical models and experimental results is finite size effects, which are an experimental reality but a theoretical challenge. One solution is periodic boundaries, which can be implemented experimentally by embedding a D-dimensional system in a D+1-dimensional space (e.g. a torus), but this can be challenging and introduces curvature. An alternative approach is to implement absorptive boundaries, such that reflections and pinning of excitations is avoided, and dynamics in the bulk mimic an infinitely extended system. Here, we experimentally investigate boundary effects in a slanted box, i.e. slox potential, which is homogeneous in the center and rises linearly at the boundary. We compare dynamics in slox and standard box traps, by studying wavepacket dynamics and reflections of high-momentum modes at the boundary. We show that the slox effectively absorbs excitations above a certain momentum-scale, which can be described in terms of finite-temperature dynamics, where damping locally increases at the boundary due to the inhomogeneous (thermal) density distribution.

Q 42.6 Wed 17:00 Philo 2. OG

Dynamics of trapped dipolar Bose gases at BEC-quantum droplet crossover — •Denis Mujo[1], Ivana Vasić[1], Milan Radonić[2,1], and Axel Pelster[3] — [1]Institute of Physics Belgrade, University of Belgrade, Serbia — [2]I. Institute of Theoretical Physics, University of Hamburg, Germany — [3]Physics Department, Rheinland-Pfälzische Technische Universität Kaiserslautern-Landau, Germany

Since the first realization of quantum droplets [1], various experiments have indicated that quantum droplets in a dipolar Bose system are stabilized due to quantum fluctuations [2,3], correcting the ground-state energy. Here we study the dynamics of trapped dipolar Bose gases using both time-dependent variational methods and full three-dimensional simulations of the extended Gross-Pitaevskii equation. Our focus is on the crossover region between a BEC and a quantum droplet, where the system becomes highly sensitive to parameter variations such as changes of the s-wave scattering length or the strength of the trapping confinement. We identify the critical conditions required to maintain droplet stability when these parameters are varied, including the effects of different variation rates and a complete removal of the trapping potential. And we examine the behavior of collective excitation modes in the vicinity of the BEC-quantum droplet crossover.

[1] H. Kadau et al., Nature **530**, 194 (2016).
[2] A.R.P. Lima and A. Pelster, Phys. Rev. A **84**, 041604(R) (2011).
[3] F. Wächtler and L. Santos, Phys. Rev. A **93**, 061603 (2016).

Q 42.7 Wed 17:00 Philo 2. OG

Supersolid from first principles with Complex Langevin. — •Luca Falzoni[1], Philipp Heinen[1], and Thomas Gasenzer[1,2,3] — [1]Kirchhoff-Institut für Physik, Uni Heidelberg, Im Neuenheimer Feld 227, 69120 Heidelberg — [2]Institut für Theoretische Physik, Uni Heidelberg, Philosophenweg 16, 69120 Heidelberg — [3]ExtreMe Matter Institute EMMI, GSI Helmholtzzentrum für Schwerionenforschung, Planckstraße 1, 64291 Darmstadt, Germany

The experimental observation of supersolidity in dipolar gases preceded its theoretical understanding, as the supersolid phase is predicted to be unstable within the extended Gross–Pitaevskii equation (eGPE). Current theoretical stabilization relies on heuristic corrections, typically implemented via an *ad-hoc* $\propto |\psi|^5$ term motivated by the Lee–Huang–Yang (LHY) contribution. To consistently go beyond the LHY correction, a quantum-exact approach is required. In this work, we demonstrate that the Complex Langevin method provides a fully nonperturbative, first–principles description of the supersolid regime and successfully captures the emergence of stable supersolid states.

Q 42.8 Wed 17:00 Philo 2. OG

Phase diagrams for dipolar interacting quantum gases — •Robin Ruediger Krill[1], Jan Alexander Koziol[2], Anja Langheld[2], Calvin Krämer[2], Giovanna Morigi[1], and Kai Phillip Schmidt[2] — [1]Theoretische Physik, Universität des Saarlandes, 66123 Saarbrücken, Germany — [2]Department für Physik, Friedrich-Alexander Universität Erlangen-Nürnberg, Staudtstraße 7, 91058 Erlangen, Germany

We present phase diagrams for ultracold quantum gases of dipolar bosons in an optical lattice. In the low-density regime, we map the quantum gas to a hardcore-bosonic model, where we then can use an extended Stochastic Series Expansion quantum Monte Carlo algorithm to obtain the ground state phase diagrams. Recent investigations of such systems with mean-field approaches indicate rich quantum phase diagrams including a devil's staircase of solid phases and a plethora of exotic lattice supersolids [1]. The quantum Monte-Carlo approach allows us to extend this mean-field study by fully incorporating quantum fluctuations, and thus to analyse the interplay among frustration, long-range interactions, and quantum fluctuations. We determine the phase diagram and verify the existence of supersolid phases in the low-density limit.

[1] J.A Koziol, G.Morigi, K.P. Schmidt, SciPost Phys. 17, 111 (2024)

Q 42.9 Wed 17:00 Philo 2. OG

Sine-Gordon solitons in a spinor Bose-Einstein condensate — •Florian Schmitt, Ido Siovitz, Yannick Deller, Alexander Schmutz, Raphael Schäfer, Alexander Flamm, Helmut Strobel, Markus K. Oberthaler, and Thomas Gasenzer — Kirchhoff-Institut für Physik, Universität Heidelberg, Im Neuenheimer Feld 227, 69120 Heidelberg, Germany

This contribution is concerned with the theoretical analysis of topological defects in a Bose gas governed by the spin-1 Gross-Pitaveskii equation (GPE). We find that for a spinor gas consisting of Rubidium-87 atoms a local imprint in the spinor phase leads to a stable topological defect both in experiment and numerical time evolution. It exhibits key features of a kink solution of the sine-Gordon model, and we can calculate its velocity depending on the quadratic Zeeman shift from the spin-1 GPE Lagrangian as well as from its corresponding effective sine-Gordon theory. We investigate dynamics of kink collisions with respect to the observables of the spin-1 gas and are able to relate this defect living at low spin interaction strength to the exactly solvable regime of the spin-1 GPE Lagrangian.

Q 42.10 Wed 17:00 Philo 2. OG

Topological properties of lattice solitons in the two-dimensional Harper-Hofstadter model — •Hugo Gerlitz, Julius Bohm, and Michael Fleischhauer — Department of Physics and Research Center OPTIMAS, University of Kaiserslautern-Landau, 67663 Kaiserslautern, Germany

Since the discovery of the integer quantum Hall effect, topological 2D lattice models have attracted significant interest in many-body physics. Recent experiments investigating solitons in waveguides with nonlinear Kerr media [1] have observed interaction-induced transitions between phases of integer and fractional quantized topological transport in 1D lattice models. In one-dimensional systems a quantum mechanical description of lattice solitons is typically done by exact diagonalization or tensor network approaches. These approaches are however strongly limited by system size or not suitable in higher dimensions. Mapping the interacting many-body model of quantum solitons to an effective description of compact objects in a reduced Hilbert-space was successful in reproducing topological properties in 1D models [2]. Motivated by this we here present an effective description of quantum solitons in an interacting two-dimensional Harper-Hofstadter model. With this we show the emergence of effective Peierls phases for the composite object which vary with the particle number and in particular cases can destroy the system*s topological properties altogether.

[1]: Jürgensen et. al., Nature 596, 63-67 (2021) [2]: Bohm et. al., arXiv:2506.00090 (2025)

Q 42.11 Wed 17:00 Philo 2. OG

Observation and detection of crystal phases with variable structures in dipolar quantum gases — •Jianshun Gao, Karthik Chandrashekara, Christian Gölzhäuser, Lily Platt, Julian Kusch, Rémy Dolbeault, and Lauriane Chomaz — Physikalisches Institut, Im Neuenheimer Feld 226, Heidelberg, Germany

Dipolar quantum gases have been found to display exotic phases from anisotropic superfluids, to sefl-bound fluids, and to crystalline states, also including supersolids. These phases spontaneously arise depending on the interactions parameters, trap geoemtries, and atom number in the system. In planar trap geometries, while only triangular crystalline states have yet been observed, various structures of the crystalline states have been predicted. In our experiment, we explore the phase diagram of a quantum gas of Dysprosium atoms in a surfboard-shaped trap by independently controlling the contact interaction and the dipole orientation angle. We observe that the gas transitions from a uniform superfluid to density-modulated states, with either triangular or stripe arrangement. In this poster, we will present an analyse protocol for detecting the density-modulated patterns from the high-intensity in-situ absorption imaging, and extracting the important information: number, dimensions, and anisotropy of the crystal structures, number of neighboring structures and typical distance between them.

Q 42.12 Wed 17:00 Philo 2. OG

Theoretical analysis of the mitigation of Floquet heating with multi-tone drives in a Hubbard lattice — •Carlotta Koroll and •Francesco Petiziol — Technische Universität Berlin, Germany

Floquet engineering allows for the realization of effective Hamiltonians that are difficult to access in static systems. This is achieved by driving a highly controllable quantum system with a periodic signal. However, one limitation is the gradual absorption of drive energy over time, which drags the system towards a featureless state in the long run, a process known as Floquet heating. One technique for minimizing this effect is the design of driving schemes that effectively close energy absorption channels through destructive interference. This has recently been demonstrated in experiments with ultracold atoms in optical lattices using a two-tone drive. We present a theoretical and numerical study of this mechanism in a driven Hubbard lattice. Our goal is to develop a clearer understanding of the underlying heating processes and to determine under which conditions multi-tone driving can effectively mitigate Floquet heating in interacting lattice systems.

Q 42.13 Wed 17:00 Philo 2. OG

Quantum gas microscopy of exotic Hubbard systems — •Philip Kämmle[1], Jan Deppe[1], Liyu Liu[2], Jirayu Mongkolkiatticha[2], Davis Garwood[2], Jin Yang[2], and Peter Schauss[1] — [1]Institute for Quantum Physics, University of Hamburg — [2]University of Virginia

This poster presents our recent developments in quantum simulation of electronic systems using ultra-cold atoms in geometrically frustrated lattices, as well as three-component fermionic systems that reflect the three flavors in quantum chromodynamics. We illustrate the achievement of a Mott insulator with lithium-6 on a symmetric triangular lattice, featuring a lattice spacing of 1003 nm. Through spin removal techniques, we can isolate individual spins and measure nearest neighbor spin-spin correlations across varying interaction strengths. Additionally, we expand quantum gas microscopy to three-flavor Fermi lattice gases in the Hubbard regime. Using site- and flavor-resolved detection, we investigate the phase diagram of the three-flavor Hubbard model, revealing signs of flavor-selective localization and selective pairing at temperatures as low as the tunneling energy scale. Future work aims to explore dynamical systems through transport measurements in a triangular lattice combined with digital micromirror device (DMD) and spatial light modulator (SLM) potentials, facilitating the study of transport dynamics in customized potential landscapes.

Q 42.14 Wed 17:00 Philo 2. OG

Developing a quantum gas microscope with programmable lattices — •Saumya Shah[1,2], Constanze Vogel[1,2], Sarah Waddington[1,2], Isabelle Safa[1,2], Rodrigo Rosa-Medina[1,2], and Julian Léonard[1,2] — [1]Institute of Science and Technology Austria (ISTA), Am Campus 1, 3400 Klosterneuburg, Austria — [2]Atominstitut TU Wien, Stadionallee 2, 1020 Wien, Austria

Experiments involving ultra-cold atoms in optical lattices provide powerful ways for engineering and probing strongly correlated quantum matter. The field has advanced significantly in the past few decades, offering exceptional single-site resolution and single-atom addressing. However, current setups are often restricted by rigid lattice configurations and slow cycle times. In this poster, we showcase our endeavors in building a next-generation quantum gas microscope for fermionic and bosonic lithium atoms. Utilizing auxiliary optical tweezers and direct optical cooling techniques, we aim to assemble small lattice systems with sub-second experimental cycles. We build tailored optical lattices with dynamically reconfigurable geometries by leveraging holographic projection techniques. Our approach paves the way for multiple research areas, which range from quantum simulations of fractional quantum Hall states to frustrated phases with unconventional geometries.

Q 42.15 Wed 17:00 Philo 2. OG

Programmable State Preparation of Ultracold Fermions Using Optical Tweezer Arrays — •Francesco Testi[1,2], Marcus Culemann[1], Jin Zhang[1], Naman Jain[1], and Philipp Preiss[1,3] — [1]Max Planck Institute of Quantum Optics, Garching — [2]Ludwig-Maximilians-Universität München — [3]Munich Center for Quantum Science and Technology, Munich, Germany

Ultracold atoms in optical lattices offer a powerful platform for studying interacting quantum many-body systems and non-equilibrium dynamics. However, the preparation of arbitrary initial states remains a major challenge, as conventional cooling and loading protocols naturally yield only a limited set of configurations such as Mott insulators or charge-density waves. The UniRand experiment aims to overcome this limitation by integrating an optical lattice with an array of dynamically reconfigurable optical tweezers for the preparation of programmable site- and spin-resolved arrangements of fermionic lithium-6 atoms. The poster showcases high-fidelity spin-resolved imaging, efficient loading and evaporation within the tweezer array, and deterministic control over the atomic density in each individual trap. These capabilities allow us to assemble arbitrary spin and density configurations across an 8x8 array with a rapid experimental cycle time of 2-3 s. By combining precise state preparation with fast repetition rates, this programmable-state architecture opens new opportunities for realizing fermionic quantum information protocols and engineering tailored non-equilibrium states to explore previously inaccessible regimes of the Fermi-Hubbard model.

Q 42.16 Wed 17:00 Philo 2. OG

Experimental realization of quantum Hall states with few rotating fermions — •Paul Hill, Johannes Reiter, Maciej Galka, and Selim Jochim — Physikalisches Institut, Universität Heidelberg, Im Neuenheimer Feld 226, 69120 Heidelberg (Germany)

Integer and fractional quantum Hall states constitute topological phases of matter featuring exotic macroscopic properties such as the quantization of the transverse resistivity and emergence of edge currents. Expanding upon our deterministic preparation of a spinful two-particle Laughlin state [arXiv:2402.14814], we present the recent observation of an integer quantum Hall state of six rapidly rotating fermions confined in a tight optical tweezer. Furthermore, we discuss how to explore topological transitions between integer and fractional quantum hall states with our platform, and how off diagonal elements of the density matrix, in the form of probability currents, can be measured.

Q 42.17 Wed 17:00 Philo 2. OG

Phases of Matter in Few Fermions with Dipolar Interactions — •Tim Pohlmann, Ximeng Song, Paula Seyfert, Lennart Naeve, Lennart Hoenen, Philipp Lunt, and Lauriane Chomaz — Physikalisches Institut Universität Heidelberg, Im Neuenheimer Feld 226, 69120 Heidelberg

In this poster, we theoretically investigate few spin-polarized fermions with strong dipolar interactions in a two-dimensional harmonic trap. This project comes alongside of the construction of a new 161Dy experiment. We numerically find the ground states of the Hamiltonian by exact diagonalization for different particle numbers and various tilting angles of the dipoles. The competition of the dipolar interaction strength and directivity, Fermi energy and harmonic oscillator frequency results in a rich phase diagram[1]. This includes anisotropic pairing suggesting the emergence of p-wave superfluidity, and Wigner crystallization at large dipolar interactions[2, 3].
References: [1] Anne-Louise Gadsbølle and G. M. Bruun. Harmonically trapped dipolar fermions in a two-dimensional square lattice. Phys. Rev. A, 85:021604, Feb 2012. [2] G. M. Bruun and E. Taylor. Quantum phases of a two-dimensional dipolar fermi gas. Phys. Rev. Lett., 101:245301, Dec 2008. [3] J. C. Cremon et al. Tunable wigner states with dipolar atoms and molecules. Phys. Rev. Lett., 105:255301, Dec 2010.

Q 42.18 Wed 17:00 Philo 2. OG

Shielding of ultracold Lithium-6 — •Finn Lubenau, Daniel Dux, Tim Schiffer, Tobias Hammel, Maximilian Kaiser, Matthias Weidemüller, and Selim Jochim — Physikalisches Institut, Heidelberg, Germany

We are presenting the Heidelberg Quantum Architecture [1], a modular quantum gas platform creating a degenerate fermi gas of ^{6}Li, that combines individual modules to implement a large variety of functionalities, that can be quickly updated and exchanged.

Here, we will report on the implementation of an optical dipole trap module at 812 nm near the $2P \longleftrightarrow 3S$ resonance. While the imaging transition used in our system is the D2-line of ^{6}Li at 671 nm between the $2S$ and $2P$ fine structure levels, the 812 nm trap introduces a large light shift of the $2P$ level, as this level has a diverging polarisability at this wavelength, effectively detuning the imaging transition from the imaging laser. This allows for site selective shielding of the atoms and thus enables partial probing of the system.

Additionally, we present a spatial light modulator (SLM) module to create precise and reproducible tuneable light fields, including the ability to correct for optical aberrations and in-shot dynamic repositioning of the atoms.

[1]: T. Hammel, M. Kaiser et al., Modular quantum gas platform, Phys. Rev. A **111**, 033314

Q 42.19 Wed 17:00 Philo 2. OG

Upgrades for the modular quantum gas platform — •Tim Schiffer, Tobias Hammel, Daniel Dux, Finn Lubenau, Maximilian Kaiser, Matthias Weidemüller, and Selim Jochim — Physikalisches Institut, Heidelberg, Germany

The Heidelberg Quantum Architecture [1] is a modular quantum gas platform, consisting of disentangled modules forming a versatile cold atom experiment.

Here, optical units allow flexible trap geometries, fast reconfiguration and precise mechanical alignment, enabling straightforward adaptation to evolving experimental requirements in our Lithium-6 experiment.

On this poster, we report on the progress made implementing self-aligning modules and modules with increased stability. We discuss the already implemented experimental toolbox, containing optical tweezers, repulsive potentials shaped by a DMD and single-atom and spin-resolved imaging.

[1]: T. Hammel, M. Kaiser, et al., Modular quantum gas platform, Phys. Rev. A **111**, 033314

Q 42.20 Wed 17:00 Philo 2. OG

Design and Optimization of a Zeeman Slower for Ultracold Fermionic Dysprosium Experiments — •Ximeng Song, Paula Seyfert, Tim Pohlmann, Lennart Naeve, Lennart Hoenen, Philipp Lunt, and Lauriane Chomaz — Physikalisches Institut (Universität Heidelberg), Im Neuenheimer Feld 226, 69120 Heidelberg

Producing a high-flux, cool beam of atoms from a high-temperature, effusive oven is a fundamental prerequisite for any ultracold quantum gas experiment. The complex hyperfine structure of lanthanide atoms, such as Dysprosium, can render standard two-dimensional magneto-optical traps (2DMOT) inefficient due to optical pumping into dark states.

In this work, we present detailed analysis and optimization of a combined Zeeman slower (ZS) and 2DMOT as a primary cooling stage for ^{161}Dy, based on analytical modelling and numerical simulations using the full 216-level hyperfine structure of the 421-nm cycling transition. We determine optimal magnetic-field profiles, laser detunings, and capture velocities. Crucially, the output of the ZS is matched to a low-gradient 2DMOT, whose parameters were likewise optimized for efficient capture of ^{161}Dy at the reduced velocities. The combined ZS-2DMOT system yields a substantial increase in expected atomic flux into the science chamber, providing an experimentally feasible design for the precooling stage of our new fermionic dysprosium experiment.

References: S. Eckel, D. S. Barker, E. B. Norrgard, and J. Scherschligt. PyLCP: A Python package for computing laser cooling physics. Computer Physics Communications 270 (2022).

Q 42.21 Wed 17:00 Philo 2. OG

Hybrid analog-digital quantum simulation with a quantum gas microscope — •Dorothee Tell[1], Si Wang[1], Petar Bojović[1], Johannes Obermeyer[1], Marnix Barendregt[1], Immanuel Bloch[1,2], and Titus Franz[1] — [1]Max Planck Institute of Quantum Optics, Garching, Germany — [2]Fakultät für Physik, Ludwig-Maximilians-Universität, 80799 Munich, Germany

Simulating strongly correlated electronic systems is a significant challenge for classic numerical methods which can be overcome by native quantum systems. Both analog simulators that reconstruct the Hamiltonian and allow reading out snapshots of the wave function, or digital systems where the problem is encoded in a qubit platform have shown impressive results exploring special phases of matter.

In our quantum gas microscope we observe fermionic lithium atoms with single-site and spin resolution. We demonstrate state-of-the-art analog and digital tools, which have recently allowed us to study the universal scaling of correlations in doped Fermi-Hubbard systems at the onset of the pseudogap phase [1], high-fidelity collisional quantum gates [2], and spontaneous strong-to-weak symmetry breaking. With these methods at hand, we are aiming towards measuring signatures of high-temperature superconductivity by using a hybrid analog-digital scheme that allows us to perform basis transformations and thereby enables us to measure more relevant quantities [3].

[1] T. Chalopin et al., arXiv:2412.17801 (2024)
[2] P. Bojović et al., arXiv:2506.14711 (2025)
[3] H. Schlömer et al., PRX Quantum 5 (2024)

Q 42.22 Wed 17:00 Philo 2. OG

Towards Fermionic Systems with Dipolar Interactions — •Paula Seyfert, Tim Pohlmann, Ximeng Song, Lennart Naeve, Lennart Hoenen, Philipp Lunt, and Lauriane Chomaz — Physikalisches Institut (Universität Heidelberg), Im Neuenheimer Feld 226, 69120 Heidelberg

We are constructing a new experimental platform to study spin-polarized fermionic systems with strong dipolar interactions under the microscope. The competition of the Fermi energy with the long-range dipolar interactions, alongside the high degree of control on atom number, dipolar strength and orientation offer a rich platform to study exotic quantum many-body phenomena [1].

We adapt the species-agnostic modular quantum gas platform [2] originally developed for ^{6}Li in the group of Selim Jochim to fermionic ^{161}Dy, which possesses one of the largest magnetic moments ($\mu = 10\mu_B$). To tackle the more complicated cooling of this lanthanide atom encompassing a complex hyperfine structure, we implement a compact design of a permanent-magnet Zeeman-Slower and 2D MOT. In the science chamber, consisting of a nano-textured glass cell, the final trapping stage will be a core-shell 3D MOT. In this poster, I will showcase the current status of the design and construction.

References: [1] A.-L. Gadsbølle and G. M. Bruun, 'Harmonically trapped dipolar fermions in a two-dimensional square lattice', Phys. Rev. A 85.2 (Feb. 2012). [2] Tobias Hammel et al., 'Modular quantum gas platform', Phys. Rev. A 111, 033314 (Mar. 2025).

Q 42.23 Wed 17:00 Philo 2. OG

Individual cooler and repumper power stabilisation for counting 6Li-atoms — •Armin Mirzaei Kian, Johannes Reiter, Paul Hill, Maciej Galka, and Selim Jochim — Physikalisches Institut, Universität Heidelberg, Deutschland

Precise counting of the number of atoms in a magneto-optical trap down to the single atom level relies on the high-fidelity discrimination between atoms based on their total fluorescence intensity. Experimentally, the latter is altered by laser power fluctuations. In this work we present a technique to improve the signal to noise ratio of counting 6Li-atoms by frequency modulation of the cooler and repumper beams. This method is chosen since the combined beam is indinstinguishable in its properties like polarisation and mode except the small frequency difference resulting in a beat note. Modulating the Acousto-Optic-Modulators of both cooler and repumper by two frequencies respectively, additional sidebands are generated whose amplitudes are proportional to the optical powers of the beams. With subsequent demodulation these signals can be used to feedback and stabilise cooler and repumper power individually, leading to a stronger discrimination of atom number.

Q 42.24 Wed 17:00 Philo 2. OG

Experimental setup for trapping ultracold atoms near 4K solid state samples — •Valerie Leu, Julia Gamper, Cedric Wind, Wolfgang Alt, and Sebastian Hofferberth — Institute of Applied Physics, University of Bonn, Germany

In our experiment we are developing an experimental platform that couples Rydberg atoms to an electromechanical resonator on an atom chip operated in a cryogenic environment. To support the use of interchangeable atom chips, both the experimental apparatus and the cryostat must be engineered so that the chip assembly can be mechanically decoupled from the surrounding system, ensuring reliable removal and replacement of the chips.

This poster presents our progress on constructing this platform. The setup consists of a region for trapping and cooling rubidium atoms in a magneto-optical trap, as well as a cryogenic stage in which the atoms will be coupled to an electromechanical resonator integrated on the atom chip. We describe the design of the cryogenic system and the implementation of a rail-based mechanism that allows the system to be opened, the atom chip to be inserted or exchanged, and the entire assembly to be closed again in a controlled and reproducible manner. This will allow future studies of Rydberg atoms near 4 K surfaces and pave the way for initial experiments on coupling of the atoms to an on-chip microwave source.

Q 42.25 Wed 17:00 Philo 2. OG

Stabilizing a continuous family of quantum many-body scarred states in the PXP model using periodic driving — •Stefan Malijević and Ana Hudomal — Institute of Physics Belgrade, University of Belgrade, Serbia

Experiments on Rydberg atom arrays have revealed a novel class of quantum systems in which a small subset of atypical eigenstates, known as quantum many-body scars, gives rise to persistent revivals and suppresses thermalization for specific initial states [1]. In the strongly interacting regime, this behavior is effectively captured by the PXP model. Recent experiments have shown that periodic driving, when tuned to optimal parameters, can further enhance scar-induced revivals [2]. However, previous studies of the driven PXP model have primarily focused on a few simple initial product states [3]. In this work, we consider a recently discovered continuous family of scarred states in the PXP model with chemical potential, which includes highly entangled states near the quantum phase transition [4]. Using numerical simulations of the periodically driven model, we analyze the response of these states to different driving protocols and identify regimes in which periodic modulation most effectively stabilizes the scarred dynamics.

[1] M. Serbyn et al., Nat. Phys. 17, 675 (2021).
[2] D. Bluvstein et al., Science 371, 1355 (2021).
[3] A. Hudomal et al., PRB 106, 104302 (2022).
[4] A. Daniel et al., PRB 107, 235108 (2023).

Q 42.26 Wed 17:00 Philo 2. OG

Imaging transverse interactions between Rydberg polaritons — •Daniil Svirskiy[1], Bankim Chandra Das[2], Matthias Metternich[1], Enrico Huland[1], Benedikt Beck[1], Nina Stiesdal[1], Wolfgang Alt[1], Ofer Firstenberg[2], and Sebastian Hofferberth[1] — [1]Institute of Applied Physics, University of Bonn, Germany — [2]Weizmann Institute of Science, Rehovot, Israel

Realization of photon-photon interaction is possible via a medium with strong optical nonlinearities, for instance, with a cloud of ultracold Rydberg atoms, where single photons propagate through the atomic medium as interacting Rydberg polaritons under the condition of electromagnetically induced transparency. Most experiments to date were aiming towards 1D systems, where the Rydberg polaritons only interact along their propagation direction and also, only time domain correlations were mainly studied.

On our poster, we will discuss the current approach to probing transverse interactions by detecting transmitted photons with a single-photon-sensitive EMCCD camera. We will also show first experimentally measured images and compare them with numerical simulations based on our 2D model that captures how transverse interactions become imprinted on the outgoing light field. These measurements will provide us with an access to the direct observation of the transversal Rydberg blockade effect. Furthermore, we show the integration of the EMCCD camera in our experimental setup. The EMCCD timing, the pulse sequence in the experiment and the synchronization will be discussed in detail.

Q 42.27 Wed 17:00 Philo 2. OG

Nonlinear Quantum Optics and Rydberg Molecules in Ultracold Ytterbium — •Anthea Nitsch[1], Chris George[1], Tangi Legrand[1], Milena Simić[2], Eduardo Uruñela[1], Xin Wang[1], Wolfgang Alt[1], Matthew Eiles[2], and Sebastian Hofferberth[1] — [1]Institute of Applied Physics, University of Bonn, Germany — [2]Max Planck Institute for the Physics of Complex Systems, Germany

Mapping the strong interactions between Rydberg excitations in ultracold atomic ensembles onto photons enables the achievement of high optical nonlinearities at the single-photon level. Previous demonstrations of this concept have relied exclusively on alkali atoms. In contrast, two-valence-electron species like ytterbium offer unique advantages, including narrow-linewidth laser cooling and, as we show for 174Yb, longer coherence times of polaritons compared to earlier Rubidium-based experiments.

In this poster, we present the latest upgrades and results from our ytterbium apparatus, featuring a flat-top beam to suppress repulsion of ground state atoms and realize photon-photon interactions via Rydberg polaritons. By minimizing frequency noise, we may extend Rydberg polariton coherence times. This is demonstrated by characterizing near-UV laser noise using a portable Mach-Zehnder interferometer. We show electromagnetically induced transparency and Rydberg blockade induced anti-bunching of photons and slow light. We also report the spectroscopic characterization of ultra-long-range ytterbium Rydberg molecules that arise as bound states in the low energy scattering of a highly excited Rydberg electron and a ground state atom.

Q 42.28 Wed 17:00 Philo 2. OG

Long-Range Enhanced Robust Quantum State Transfer in Topological Rydberg Models — •Siri Raupach, Mathias B. M. Svendsen, and Beatriz Olmos — Institut für Theoretische Physik, Universität Tübingen, Auf der Morgenstelle 14, 72076 Tübingen, Germany

Fast and robust quantum state transfer (QST) between distant nodes in a quantum network is essential in quantum information processing. We present a framework for robust topological QST in a quantum optical realization of the extended SSH and Rice-Mele model with bipartite long-range hoppings. In quasi one dimensional chains of long-range dipole-dipole coupled Rydberg atoms on two spatially offset sublattices, the topological phase depends on this spatial offset and manifests as topologically protected edge states in the non-trivial regime. Thus, robust edge-to-edge QST of a Rydberg excitation can be achieved by varying the sublattice offset adiabatically. In chains consisting of both odd and even numbers of atoms, the transfer efficiency depends on the specifics of the transfer path. Notably, we find that the transfer efficiency is significantly improved when considering realistic long-range hoppings compared to the standard case of nearest neighbor hoppings. The resulting transfer can be implemented well within the lifetime of the Rydberg atoms, and due to its topological nature is robust against positional disorder of the atoms within experimentally realistic tolerances.

Q 42.29 Wed 17:00 Philo 2. OG

Effects of spin-phonon coupling on Rydberg facilitation in a lattice — •Benno Bock, Daniel Brady, and Michael Fleischhauer — University of Kaiserslautern-Landau, Kaiserslautern, Germany

In recent years, Rydberg atoms have proven themselves as a powerful tool for quantum simulators, one of the reasons being their strong and long-ranged interactions. One interesting phenomenon resulting from these interactions is Rydberg facilitation, or anti-blockade, where an atom excited to the Rydberg state moves a neighboring atom into resonance with a laser field, thus facilitating a fast excitation cascade in a regular lattice of trapped atoms. However, along with strong dipolar interactions between Rydberg atoms (spins), come mechanical forces coupling Rydberg atoms to high motional states (phonons) in their respective tweezer traps. For a chain of atoms trapped in tweezer arrays under the facilitation constraint, we numerically simulate the dynamics of the spin-phonon coupling. To this end, we approximate the van-der-Waals interaction potential up to second order. In particular we investigate how the motional degrees of freedom affect the spreading dynamics of Rydberg excitations and indentify parameter regimes of distinct behaviors not seen in previous work [PRL 132, 133401 (2024)], such as Bloch oscillations of excitation chains and a localization regime.

Q 42.30 Wed 17:00 Philo 2. OG

Active magnetic field stabilization for a dipolar quantum gas experiment — •Tim Jeglortz, Paul Uerlings, Fiona Hellstern, Kevin Ng, Michael Wischert, Stephan Welte, Ralf Klemt, and Tilman Pfau — 5. Physikalisches Institut and Center for Integrated Quantum Science and Technology (IQST), Universität Stuttgart, Pfaffenwaldring 57, 70569 Stuttgart, Germany

We aim to experimentally investigate the fundamental low-lying excitations of a dipolar quantum gas of dysprosium atoms in a toroidal trap. In particular, we focus on the emergence of the Higgs amplitude mode across the transition from a superfluid to a supersolid as an indicator of spontaneous symmetry breaking. Precise control of the magnetic field is crucial, as the excitation energy close to the critical point in the phase diagram has a steep dependence on the relative dipolar interaction strength, serving as the control parameter, which is in turn set by a magnetic offset field in the vicinity of a Feshbach resonance. This necessitates sub-mG magnetic field stability.

This poster presents a solution for an active magnetic field stabilization setup that allows to attenuate fluctuations relative to an arbitrary offset magnetic field using an array of fluxgate sensors placed outside the science chamber. A digital stabilization loop that runs on a fast microcontroller including high-resolution analog-to-digital and digital-to-analog converters in combination with a dedicated set of field coils allows to infer and control the magnetic field at the site of the atoms and reduce the background noise, particularly power line noise at 50 Hz, up to a bandwidth of 1 kHz.

Q 42.31 Wed 17:00 Philo 2. OG

Velocity field extraction from ultracold gases using bragg scattering — •hanyi jang, elinor kath, jelte duchene, helmut strobel, and markus k. oberthaler — Kirchhoff-Institut für Physik, Heidelberg, Germany

An ultracold quantum gases velocity field offers information about phase, topological defects and transport mechanisms. We have developed a method of estimating the velocity field by Bragg scattering from a moving optical lattice, which enables velocity selective two-photon transition between momentum states. To reconstruct the spatial velocity field of a 2-dimensional Bose-Einstein condensate (BEC), we explored two techniques. A short Bragg pulse generates a broad band response that simultaneously probes a spectrum of velocities, which is advantages for non-reproducible systems. In contrast, a long Bragg pulse produces narrow spectral response that probes single velocity with a higher precision. To assess the performance of the two methods, we benchmark them experimentally on a well-controlled scenario of stationary single vortex in the BEC. We extract the radial velocity profile centered on the vortex core and compare it to the analytic theory prediction and Gross-Pitaevskii simulation.

Q 42.32 Wed 17:00 Philo 2. OG

Towards an optical lattice for lithium-6 at 841 nm — Christian Partes and •Magnus Rusch — Universität Tübingen, Physikalisches Institut, Auf der Morgenstelle 14, 72076 Tübingen

We present the status of our technical preparation for imaging lithium-6 (Li) atoms in a two-dimensional optical lattice using optical tweezers. The lattice operates at 841 nm to match the tune-out wavelength of erbium which is used for sympathetic cooling.

Due to the low mass of the Li atoms, high-frequency intensity noise of the lattice beam may cause significant heating of the gas, so the laser power has to be actively stabilized up to the MHz-range. We provide insight into the current status of our intensity control setup making use of an acousto-optic modulator and an FPGA-based PI-controller.

Additionally, we present the preparation of a two-dimensional optical tweezer array using a spatial light modulator (SLM) and near-resonant light. The SLM phase pattern is controlled by a two-stage Gerchberg-Saxton algorithm, employing both numerical and camera feedback. We aim for a tweezer distance equal to twice the lattice spacing.

Q 43: Poster – Quantum Systems

Open Quantum Systems; Collective Effects and Disordered Systems; Optomechanics; Quantum Systems between Bose and Fermi statistics

Time: Wednesday 17:00–19:00 Location: Philo 2. OG

Q 43.1 Wed 17:00 Philo 2. OG

Markovian feedback control of interacting models — •Allano Gregor Johannes Celestino Maritano[1], André Eckardt[1], and Ling-Na Wu[2] — [1]Technische Universität Berlin, Berlin, Germany — [2]Hainan University, Haikou, China

We study Markovian feedback control for state preparation and cooling of bosonic atoms in a one-dimensional optical lattice, building on a recently proposed scheme for measurement-based feedback. Using weak homodyne detection and feedback control, we explore how to steer the system towards selected many-body eigenstates with high fidelity in regimes dominated by strong interactions.

In this context, we analyze the time evolution of the system under feedback, exploring optimal control strategies for settling to the steady state and the relation between the Hamiltonian eigenstates and the resulting steady state. Overall, the project aims at identifying feedback and measurement operator structures that accelerate convergence to steady states in strongly interacting systems, thereby improving control performance and enabling future experiments on excited eigenstates and quantum transport phenomena in optical lattices.

Q 43.2 Wed 17:00 Philo 2. OG

Absence of Entanglement Growth in Dicke Superradiance — •Nico Bassler — TU Darmstadt, Institute for Applied Physics, Hochschulstraße 4A, D-64289 Darmstadt, Germany

Dicke superradiance describes an ensemble of N permutationally invariant two-level systems collectively emitting radiation with a peak radiated intensity scaling as N^2. Individual Dicke states are typically entangled. However, the density matrix during superradiant decay is a mixture of such states, raising the subtle question of whether the total state is entangled or separable. We resolve this by showing analytically that for any N, starting from the fully excited state, the collective decay preserves separability for all times. This answers a longstanding question on the role of entanglement in Dicke superradiance and underscores that, despite collective dissipation, separable states remain separable under these dynamics.

Q 43.3 Wed 17:00 Philo 2. OG

Optimal control of arbitrary perfectly entangling gates for open quantum systems — •Adrian Romer, Daniel Reich, and Christiane P. Koch — Dahlem Center for Complex Quantum Systems, Freie Universität Berlin, Berlin, Germany

Perfectly entangling gates (PE) are crucial for various applications in quantum information. One method to realize these gates is with the help of an external control field, whose concrete shape is found using optimal control theory. Instead of optimizing the shape that realizes a specific gate, the optimization target can be extended to the full set of PE. This increases the flexibility of optimization and allows to find the best PE from the set of all PE. First, we show that it is possible to construct the unitary part of an unknown coherent evolution by propagating specifically tailored density matrices. We then extend this construction method to approximate the unitary part of a non-unitary evolution. Lastly, we employ this method to superconducting qubits, where we numerically find optimized control fields that generate maximally entangled states for a desired gate duration, even if dissipation is present in the system.

Q 43.4 Wed 17:00 Philo 2. OG

Perturbative Construction of Thermodynamically Consistent Master Equations — •Shreesha Shreepad Hegde and Christiane Koch — Freie Universität Berlin, Berlin, Germany

Constructing thermodynamically consistent master equations for multipartite open quantum systems requires knowledge of the energy eigenbasis of the total system. However, this is a computationally demanding task that typically involves the diagonalisation of large Hamiltonians. The so-called local approach circumvents this problem by constructing the master equation in the product basis of the local energy eigenbases. This is consistent with zeroth-order perturbation theory with respect to the interactions within the system, but gives rise to thermodynamically inconsistent master equations in the strong coupling regime [1].

Here we suggest approaching thermodynamic consistency by accounting for the interactions within the multipartite system iteratively. To this end, we combine a perturbation theory with block diagonalisation of the total Hamiltonian. This allows us to iteratively add higher-order corrections to the zeroth-order energy eigenbasis provided by the local approach. Subsequently, using the corrected eigenbasis, we derive master equations whose thermodynamic consistency can be tested at higher orders.

[1] A. Levy, R. Kosloff, "The local approach to quantum transport may violate the second law of thermodynamics", EPL 107, 20004 (2014).

Q 43.5 Wed 17:00 Philo 2. OG

Cavity-induced chiral states in two-dimesional fermi gas — •Aleksander Wagner — Physikalisches Institut, University of Bonn

We investigate topological out-of-equilibrium phases in a driven two-dimensional Fermi-Hubbard model with strong light-matter interactions induced by a dissipative optical cavity. The cavity induces phase-imprinted hopping along a lattice direction where tunneling is otherwise suppressed. Above a critical light-matter coupling strength, this process leads to a collective amplification of hopping and generates a dynamical gauge field, yielding an effective description reminiscent of the Hofstadter Hamiltonian. Moving beyond purely Hamiltonian frameworks, we characterize the steady state of the resulting open quantum system, shaped by the interplay of external driving, quantum fluctuations, and dissipation. We map out the associated non-equilibrium phase diagram and examine the emergence and stability of localized edge states and chiral edge currents in the presence of fluctuations. Our results provide insights into how robust topological phenomena in open quantum systems can be engineered and controlled.

Q 43.6 Wed 17:00 Philo 2. OG

Imaginary-Time Truncated Wigner Approximation for the simulation of many-body spin-1/2 systems — •Tom Schlegel, Jens Hartmann, Dennis Breu, and Michael Fleischhauer — RPTU Kaiserslautern, Kaiserslautern, Germany

The recently developed Truncated Wigner Approximation (TWA) for spins [1] is a semiclassical method to describe interacting spin-1/2-systems including dephasing and decay. Instead of finding exact solutions in the exponentially growing Hilbert space, the method employs a mapping from the equation of motion of many-body density matrix to stochastic differential equations of classical variables in a continuous phase space. The method, which improves on a mean-field description by including leading order quantum corrections, was successfully employed to simulate the real-time dynamics of several models.

We here further develop the TWA method to an imaginary-time evolution, i.e. for the simulation of finite-temperature states and ground states of interacting spin systems. Specifically we derive the imaginary-time TWA for spin-1/2-systems, highlight emerging problems and discuss how to deal with them. We then benchmark the method for single-particle Hamiltonians. In order to assess the ability of the TWA method to faithfully describe quantum phase transitions, we analyze the one and two-dimensional transverse-field Ising model finding rather good agreement of the critical behavior simulated by TWA with exact results.

[1] C. Mink et al., PhysRevResearch.4.043136

Q 43.7 Wed 17:00 Philo 2. OG

Floquet theory for quantum systems driven by nonclassical light fields — •Vladislav Sukharnikov and Frank Schlawin — Universität Hamburg, Luruper Chaussee 149, 22761 Hamburg, Germany

Controlling properties of materials by periodic drive has become an important research frontier, typically referred to as Floquet engineering. It has already enabled many advances in condensed-matter physics, such as inducing topological effects and nontrivial energy bands. Here, we explore Floquet engineering when the drive is a quantum light field. This introduces additional degrees of freedom and opens new possibilities for manipulating matter far from equilibrium.

We analyze how a nonclassical drive–for example, a bright squeezed vacuum–alters the properties of periodically driven quantum systems. Building on a previously developed approach to open-system dynamics [arXiv:2511.01358], we recast the interaction between a quantum system and a squeezed light into a time-local master equation with periodic coefficients. This framework allows us to study how time-periodic driving reshapes the effective Hamiltonians of quantum materials through Floquet engineering. We examine drive-induced correlations and analyze the potential for enhancing effects achievable with classical light.

Q 43.8 Wed 17:00 Philo 2. OG

Quantum Many-Body Dynamics in a Discrete Phase Space — •Maxence Pandini and Johannes Schachenmayer — CESQ, University of Strasbourg, France

The Discrete Truncated Wigner Approximation (DTWA) is a powerfull tool to simulate many-body dynamics of finite size quantum systems. Coupled to the Truncated Wigner Approximation, this opens the possibility to simulate many-body spin-boson systems with a high number of particles (N~10000) with only a linear numerical complexity. In this work, we show the advances of finding rigorously a DTWA with a Discrete Phase Space formalism of quantum mechanics, doing a direct parallel with the continuous Wigner-Weyl phase space formalism of quantum mechanics.

Q 43.9 Wed 17:00 Philo 2. OG

Fluctuations of thermal Lorentz-Hall forces inside a nonlocal conductor — •Alexander Schomburg and Carsten Henkel — Universität Potsdam, Institut für Physik und Astronomie, Germany

The Brownian motion of charges inside conductors can be treated as a fluctuating macroscopic current density, giving rise to fields that inherit the sources' stochastic properties [1]. The mean magnetic (Lorentz) force density [2] represents a second-order correlation function of these quantities while the force autocorrelation is given in turn by fourth-order correlations. These can be reduced to the spectrum of current fluctuations. In the nonlocal treatment, the resulting expressions involve both the transverse and longitudinal parts of the dielectric function. We analyse the convergence of the frequency integrals and of the Lorentz force evaluated at the surface.

[1] S. Rytov, Y. Kravtsov and V. Tatarskii, Principles of Statistical Radiophysics 3: Elements of Random Fields (Springer, 1989)

[2] C. Henkel, Physics 6 (2024) 568

Q 43.10 Wed 17:00 Philo 2. OG

Experimental study of collective scattering beyond short-term burst dynamics — •Benedikt Saalfrank, Yoan Spahn, Thomas Halfmann, and Thorsten Peters — Institut für Angewandte Physik, Technische Universität Darmstadt, Hochschulstraße 6, 64289 Darmstadt, Germany

We experimentally investigate collective light scattering in a dilute, disordered ensemble of atoms confined within a hollow-core fiber. Starting from a fully inverted effective two-level system, we observe - under specific experimental conditions - scattering dynamics that persist beyond the short-term superfluorescent burst, indicating the presence of subradiant decay channels. By analyzing the autocorrelation function of the emitted light while accounting for temporal jitter and technical noise, we extract the intrinsic temporal correlations of the collective emission. In addition, we perform time-resolved measurements of the excited-state population during the decay. This combined approach allows us to quantify the fraction of atoms remaining in the initial state and relate it to the observed late-time decay rate.

Q 43.11 Wed 17:00 Philo 2. OG

Simulation of motion-induced unidirectional collective emission with the Truncated Wigner Approximation — •Jens Hartmann[1], Yoan Spahn[2], Benedikt Saalfrank[2], Thorsten

Peters[2], and Michael Fleischhauer[1] — [1]RPTU Kaiserslautern-Landau, Kaiserslautern, Germany — [2]TU Darmstadt, Darmstadt, Germany

We discuss the first observation of motion-induced unidirectionality in the collective emission of atoms confined within a hollow-core waveguide. To understand the underlying effect we use the Truncated Wigner Approximation for spins [1, 2] to simulate the collective emission of an effective number of moving atoms coupled to a waveguide. We see good agreement between experimental results and the theoretical description and can show that this behaviour arises because the decay occurs via a Raman-process-based effective two-level system with a spatially-dependent phase of the transition dipole moment. We derive a simple effective model of static emitters that includes positional uncertainty and leads to an effective non-isotropic collective coupling. Furthermore, we study the second-order correlation function of the emitted light close to and well above the threshold to collective emission, showing a buildup of coherence during the superfluorescent bursts while the emitted light below the threshold exhibits thermal statistics.

[1, 2] C. Mink et al., 10.21468/SciPostPhys.15.6.233, PhysRevResearch.4.043136

Q 43.12 Wed 17:00 Philo 2. OG

Simulations of superradiance in cold atom experiments — •Rémy Dolbeault[1], Arfor Houwman[2], Lauriane Chomaz[1], Wyatt Kirkby[1], Karthik Chandrashekara[1], Jianshun Gao[1], Christian Gölzhäuser[1], Lily Platt[1], and Francesca Ferlaino[2] — [1]Universiy of Heidelberg — [2]University of Innsbruck

We present simulations of superradiance in ultracold gases of highly magnetic atoms with specific geometries (lattice or self-ordering droplets).

Superradiance occurs when an initially excited system of interacting atoms decays faster than independent atoms due to the build-up of interatomic correlations. As density (and geometry in the case of anisotropic interactions) plays a key role in the evolution of superradiant systems, two different situations were investigated:

- An optical lattice of Erbium atoms, corresponding to the setup of the Erbium team in Innsbruck, and the diminishing effect of the magnetic dipole-dipole interaction on superradiance
- Quantum droplets of Dysprosium atoms corresponding to the BoDy experiment in Heidelberg

Using a symbolic derivation of the meanfield plus correlations equations from the Lindblad master equation, the simulation of the time evolution of up to 75 atoms can be performed, giving access to first insights into the dynamics of real experimental systems (with atom number typically around 10^4 atoms).

Q 43.13 Wed 17:00 Philo 2. OG

Disorder-Enhanced and Disorder-Independent Transport with Long-Range Hopping: Application to Molecular Chains in Optical Cavities — Nahum C. Chávez[1], •Francesco Mattiotti[2], J. A. Méndez-Bermúdez[3], Fausto Borgonovi[1,4], and G. Luca Celardo[5] — [1]Dipartimento di Matematica e Fisica, Università Cattolica, Brescia, Italy — [2]Theoretische Physik, Universität des Saarlandes, Saarbrücken, Germany — [3]Benemérita Universidad Autónoma de Puebla, Instituto de Física, Mexico — [4]INFN, Sezione di Milano, Milano, Italy — [5]Department of Physics and Astronomy, University of Florence, Italy

Overcoming the detrimental effect of disorder at the nanoscale is very hard since disorder induces localization and an exponential suppression of transport efficiency. Here we unveil novel and robust quantum transport regimes achievable in nanosystems by exploiting long-range hopping. We demonstrate that in a 1D disordered nanostructure in the presence of long-range hopping, transport efficiency, after decreasing exponentially with disorder at first, is then enhanced by disorder [disorder-enhanced transport (DET) regime] until, counterintuitively, it reaches a disorder-independent transport (DIT) regime, persisting over several orders of disorder magnitude in realistic systems. To enlighten the relevance of our results, we demonstrate that an ensemble of emitters in a cavity can be described by an effective long-range Hamiltonian. The specific case of a disordered molecular wire placed in an optical cavity is discussed, showing that the DIT and DET regimes can be reached with state-of-the-art experimental setups.

Q 43.14 Wed 17:00 Philo 2. OG

Feedback cooling scheme for small nanoparticles based on single-photon detection — •Luis Kunkel Garcia, Klaus Hornberger, and Henning Rudolph — University of Duisburg-Essen, Faculty of Physics, Lotharstraße 1, 47057 Duisburg, Germany

Recent experiments have demonstrated center-of-mass ground state cooling of optically levitated nanoparticles by combining efficient homodyne detection of the scattered light with feedback [1,2]. Here, we theoretically analyze a feedback cooling scheme based solely on the detection of individual scattered photons, which paves the way for ground state cooling in previously inaccessible mass regimes. The scheme involves a continuous measurement of photon counts, generating a state estimation, from which a stochastic feedback force is determined. Using realistic assumptions about the detection efficiency and dark count rates, we assess the lowest attainable temperature.

[1] Magrini et al., Real-time optimal quantum control of mechanical motion at room temperature, Nature 595, 373 (2021) [2] Tebbenjohanns et al., Quantum control of a nanoparticle optically levitated in cryogenic free space, Nature 595, 378 (2021)

Q 43.15 Wed 17:00 Philo 2. OG

Symmetry assignment of few-electron states and their Coulomb splitting on molecular networks — Ludwig Schulz, Anton Bauer, and •Carsten Henkel — Universität Potsdam, Institut für Physik und Astronomie, Germany

We investigate few-electron states on a graph, as a tight-binding model of a small molecule. For rings, the dihedral group provides a complete classification of degeneracies in terms of its irreducible representations (Mulliken symbols) [1]. We sketch a graph-theoretical explanation of energy splittings due to the Coulomb interaction between electrons. Similar arguments are applied to rings with ligands and to (avoided) crossings of Zeeman spectra in a magnetic field. A key technique involves adjacency matrices for many-electron states in the occupation number representation, that encode the hopping of one or more electrons and include signs due to the fermionic symmetry and Peierls phase factors in a magnetic field.

[1] P. Atkins and R. Friedman, Molecular Quantum Mechanics (Oxford Univ Press 2005)

Q 43.16 Wed 17:00 Philo 2. OG

Bogoliubov theory of 1D anyons in a lattice — Bin-Han Tang[1], •Axel Pelster[2], and Martin Bonkhoff[3] — [1]University of Trento, Italy — [2]RPTU Kaiserslautern-Landau, Germany — [3]University of Hamburg, Germany

Anyons of the Hubbard type in 1D interpolate between bosonic and fermionic particle statistics. Their exclusion behavior is encoded in that of their parent particles, including statistical interactions dependent on the connectivity and form of the underlying Hamiltonian. Their exchange phase emerge via non-gaugable hopping processes that characteristically break spatio-temporal symmetries, away from their canonical limits. Both effects originate from density-dependent Peierls phases that are essentially non-perturbative. This results in a rich phenomenology but also in experimental challenges and the necessity of a careful theoretical treatment. To this end, we develop a generalized Bogoliubov theory for the bosonic version of the anyon-Hubbard model, maintaining periodicity in the statistical parameter and incorporating a condensation at finite momenta. We investigate the stability of the condensate and find a mean-field manifestation of the Pauli principle while transmuting from bosons to pseudo-fermions. We regularize characteristic divergences in the thermodynamic limit by the maximal momentum resolution of a finite periodic lattice. We determine the condensate depletion as well as its momentum self-consistently, and with this investigate excitations above ground-state as well as their universal parameters. We find a good agreement with Luttinger theory at weak coupling.

Q 44: Laser Technology and Applications

Time: Thursday 11:00–13:00 Location: P 2

Q 44.1 Thu 11:00 P 2

Hybrid FDTD-transfer matrix framework for fast Bragg grating response modeling — •Yasmin Rahimof, Igor A. Nechepurenko, M. R. Mahani, and Andreas Wicht — Ferdinand-Braun-Institut (FBH), Berlin, Germany

Bragg gratings play a central role in integrated photonics because they enable fine control over reflection and transmission spectra. Numerical solvers such as the finite-difference time-domain (FDTD) method can capture their full electromagnetic behavior but quickly become impractical when simulating long or complex structures due to heavy computational demands. To overcome this limitation, we introduce a modeling strategy that derives a transfer matrix method (TMM) from short-segment FDTD simulations and then reuses it to predict the response of extended gratings. By composing transfer matrices obtained from short FDTD simulations, we can rapidly reconstruct spectra for gratings that are orders of magnitude longer than the original simulation domain. This method reproduces both reflection and transmission with errors consistently under 4% compared to full FDTD, while cutting computational time by more than an order of magnitude. Our study demonstrates that the TMM provides a reliable and scalable surrogate model, enabling efficient design exploration for structures ranging from tens to hundreds of grooves. The framework offers a powerful balance between accuracy and speed, making it particularly valuable for the development of large-scale photonic components.

Q 44.2 Thu 11:15 P 2

Tunable Pulsed UV Laser System for Laser Cooling of Relativistic Bunched Ion Beams — •Tamina Grunwitz[1,2], Benedikt Langfeld[1,2], and Thomas Walther[1,2] — [1]TU Darmstadt — [2]HFHF Campus Darmstadt

In contrast to established cooling methods (e.g. electron cooling), laser cooling promises to efficiently generate narrow longitudinal momentum distributions in relativistic bunched ion beams, even at large gamma factors. Therefore, laser cooling is the only planned cooling method for the upcoming heavy-ion synchrotron SIS100 at the FAIR facility, using three laser systems simultaneously.

In this talk, we present one of these laser systems, which delivers optical pulses with adjustable durations between 46 and 734 ps at repetition rates from 1 to 10 MHz. The systems achieves the high power output required for the laser cooling applications. By employing second-harmonic generation, the system can operate at wavelengths of both 514 nm and 257 nm, with maximum average output powers of 34 W (green) and 5 W (UV), respectively. Additionally, the system can be tuned continuously in its frequency over a range of 3.4 THz in the UV, making the laser system also suitable for laser spectroscopy applications.

Q 44.3 Thu 11:30 P 2

Ultrafast optical Kerr Gate at 1 GHz repetition rate with BBS glass and thin graphite films under focused illumination — •Amr Farrag[1], Assegid M. Flatae[1], Lenorah M. Stott[2], Alessandro Lagatti[3,5], Andrea Lapini[3,4], Doris Möncke[2], and Mario Agio[1,3,5] — [1]LaboratoryofNano-Optics, University of Siegen, 57072 Siegen, Germany — [2]Inamori School of Engineering at the New York State College of Ceramics, Alfred University, Alfred, NY, 14802, USA — [3]European Laboratory for Non-Linear Spectroscopy, 50019 Sesto Fiorentino, FI, Italy — [4]Dipartimento di Scienze Chimiche, della Vita e della Sostenibilità Ambientale, Università di Parma, 43124 Parma, PR, Italy — [5]Istituto Nazionale di Ottica (INO), Consiglio Nazionale delle Ricerche (CNR), 50019 Sesto Fiorentino (FI), Italy

Ultrafast optical detection is vital for quantum technologies and nanophotonics, yet sub-picosecond processes remain challenging to resolve, especially at the single-emitter level. Optical Kerr gating (OKG) offers high detection efficiency and broadband operation, making it a strong candidate for ultrafast single-photon measurements.

We demonstrate a 1-GHz OKG scheme using bismuth-borosilicate (BBS) glass and thin graphite films, requiring <1 nJ gate-pulse energy under focused illumination. Temporal resolutions of 175 fs (BBS) and 141 fs (graphite films) are achieved. BBS glass provides a high nonlinear coefficient and sub-ps response, whereas graphene-based graphite films deliver exceptionally strong nonlinearity and are promising for integration in future on-chip ultrafast optical platforms.

Q 44.4 Thu 11:45 P 2

Development of dynamic time over threshold method for signal processing in cavity ring-down spectroscopy — Konrad Kleineidam[1,2], Hideki Tomita[1], Takumi Mochizuki[1], Ryohei Terabayashi[1], •Erik Thiel[2], Klaus Wendt[2], Kenji Shimazoe[3], Hisashi Abe[4], and Norihiko Nishizawa[1] — [1]Department of Applied Energy, Nagoya University, Japan — [2]Institut für Physik, Johannes Gutenberg-Universität Mainz, Germany — [3]The University of Tokyo, Japan — [4]National Metrology Institute of Japan (NMIJ/AIST), Japan

Cavity ring-down spectroscopy (CRDS) is a highly sensitive technique for detecting elements and isotopes in gas samples by measuring the decay rate (i. e. ring-down rate) of transmitted laser light in a high-finesse optical cavity. Typically, a high-resolution data acquisition system is used to record the time-dependent change in signal and calculate the ring-down decay rate through exponential fitting, in order to measure the molecular number density inside the cavity. By injecting photons of different wavelengths, multiple molecules can be measured simultaneously by recording their respective ring-down rates. This study explores a simplified method for acquiring decay rates using dynamic time over threshold (dToT) analysis. This method relies on the discrete recordings of timing over two dynamically changing threshold voltages instead of the full curve recording by conventional ADCs. Preliminary results suggest that this approach can effectively determine the ring-down decay rate, offering a potentially lower-cost, faster and simpler alternative to the post exponential fitting process in CRDS measurements.

Q 44.5 Thu 12:00 P 2

On-axis Laser Ranging Interferometer for Grace-like Mission — •Daikang Wei — Max Planck Institute for Gravitational Physics (Albert Einstein Institute), Hannover, Germany

The GRACE Follow-On mission's laser ranging interferometer (LRI) has demonstrated sub-nanometer precision for inter-satellite length tracking. We present a novel interferometric architecture for future GRACE-like missions, featuring an on-axis LRI that enables monoaxial transmission and reception of laser beams between two spacecraft. Our laboratory-scale prototype establishes a transponder-based laser interferometric link between two optical benches, with phase readout at a heterodyne signal of 7.3 MHz. Two independent active beam steering loops employ differential wavefront sensing (DWS) to co-align the transmitting (TX) and receiving (RX) beams. Under simulated angular jitters, the beam pointing stability is maintained below 10 $\mu\text{rad}/\sqrt{\text{Hz}}$ in the frequency range between 2 mHz and 0.5 Hz, and the fluctuation of the TX beam's polarization state induces a reduction of 0.14% in the carrier-to-noise-density ratio. Additionally, we investigate the tilt-to-length (TTL) coupling of the optical bench using dedicated rotations of the hexapod. Our results show that the on-axis LRI enables inter-spacecraft ranging measurements with nanometer accuracy, making it a potential candidate for future GRACE-like missions.

Q 44.6 Thu 12:15 P 2

Quantum-Correlated Biphotons for Two-Photon Absorption in Biomimetic Photoswitches — •Gonca Under and Oleg Kornilov — Max-Born-Straße 2A, 12489, Berlin, Germany

Spontaneous parametric down-conversion (SPDC) provides a reliable technique for generating quantum-correlated photon pairs, enabling various quantum sensing and spectroscopic applications. In this work, we demonstrate the generation and detection of biphotons produced via type-I SPDC and their characterization using a single-photon detection setup. The photon pairs are separated at a beam splitter and routed directly into two independent single-photon detectors, allowing coincidence-based identification of quantum-correlated events. After establishing the coincidence detection scheme, we couple the biphoton state into a single spatial mode to form a well-defined quantum optical probe intended for future two-photon absorption (TPA) experiments on novel biomimetic photoswitches. Owing to their non-classical correlations, such photon pairs can achieve two-photon excitation at optical powers significantly lower than classical limits, paving the way for sensitivity enhancements compared to classical illumination in quantum-enhanced spectroscopy.

Q 44.7 Thu 12:30 P 2

Heterodyne Interferometry for a Measurement of Vacuum Magnetic Birefringence — •Laura Roberts[1], Aaron Spector[2], and Todd Kozlowski[2] — [1]Max-Planck-Institut für Gravitationsphysik (Albert-Einstein-Institut) and Leibniz Universität Hannover, 30167 Hannover, Germany — [2]Deutsches Elektronen Synchrotron DESY, 22603 Hamburg, Germany

Vacuum magnetic birefringence (VMB) is a long predicted consequence of quantum electrodynamics which describes the effect where an external magnetic field turns the vacuum into an anisotropic, polarizable medium. Despite more than 40 years of experimental effort, there has yet to be a direct laboratory detection of VMB due to its incredibly small amplitude. The Any Light Particle Search II (ALPS II) at DESY currently operates a string of 24 superconducting HERA dipole magnets, each generating a 5.3 T field, with an effective length of 212 meters, along with a high-finesse optical cavity whose eigenmode propagates through the magnet bore. The ALPS II infrastructure therefore can produce a vacuum birefringence 600 times larger than the previous best VMB search, making its future for VMB promising. We discuss an optical system to perform a measurement of VMB by sensing the differential frequency changes of two orthogonal fields stabilized to resonances of a 246 m long optical cavity whose eigenmode propagates through the ALPS II magnet string. In the following we present the results of implementing a prototype of this scheme on a 19 m cavity and discuss the prospects of the full scale experiment.

Q 44.8 Thu 12:45 P 2

Probing Vacuum Magnetic Dichroism with Precision Interferometry — •Aaron Spector[1] and Laura Roberts[2] — [1]Deutsches Elektronen-Synchrotron DESY, Hamburg, Germany — [2]Max-Planck-Institut für Gravitationsphysik (Albert-Einstein-Institut) and Leibniz Universität Hannover, Hannover, Germany

An exciting new frontier in the search for physics beyond the standard model is emerging as experiments are using precision interferometry to probe the vacuum magnetic dichroism effect. Here, light propagating through a vacuum could experience additional polarization dependent optical losses in the presence of a magnetic field as some of its energy is transferred to hypothetical fields such as axion-like-particles, millicharged fermions, and dark matter "chameleons." In this talk, we propose a new method to test this effect by continuously characterizing the complex reflectivity of an optical cavity for polarization states aligned parallel and perpendicular to a modulated external magnetic field. Using this technique, it could be possible to disentangle the changes of conventional loss channels in an optical cavity, such as scattering and absorption at the mirror coatings, from sources induced by new physics interacting with the magnetic field. I will also discuss the discovery prospects of a setup utilizing the ALPS II infrastructure (24 HERA dipole magnets each providing 5.3 T magnetic fields for a length of 8.8 m) along with a 246 m long cavity and give a status report of a prototype setup implemented on a 19 m long cavity.

Q 45: Plasmonics and Metasurfaces

Time: Thursday 11:00–13:00 Location: P 3

Invited Talk Q 45.1 Thu 11:00 P 3

Quantum geometry in plasmonic metasurfaces and signatures of collective quantum phenomena — •Javier Cuerda — Institut für Angewandte Physik, TU Darmstadt, Hochschulstraße 4A, D-64289 Darmstadt, Germany — Department of Applied Physics, Aalto University School of Science, Aalto FI-00076, Finland

Plasmonic nanoparticles radiatively coupled in two-dimensional lattices, combined with organic quantum emitters, enable strong light-matter coupling, lasing, and BEC [1]. Their highly dispersive, polarization-dependent band structure, combined with time-reversal-symmetry breaking [2], produces a non-trivial quantum geometry. The organic emitters feature vibrational modes, hinting at novel collective light-matter coupling effects.

We present recent progress on these aspects. We have measured the quantum geometric tensor of a plasmonic lattice, finding a non-trivial quantum metric and a purely non-Hermitian Berry curvature [3]. We also show how vibrational modes affect dynamical superradiance in a cavity [4], enabling studies on collective quantum coherence in plasmonic metasurfaces.

[1] A. I. Väkeväinen, *et al.* Nature Comm. **11**, 3139 (2020).

[2] F. Freire-Fernández, J. Cuerda, *et al.* Nature Phot. **16**, 27 (2022).

[3] J. Cuerda, J. M. Taskinen, N. Källman, L. Grabitz, and P. Törmä. Phys. Rev. Res. **6** (2), L022020 (2024).

[4] L. Freter, P. Fowler-Wright, J. Cuerda, B. W. Lovett, J. Keeling, and P Törmä. Accepted for publication. arXiv:2305.13244 (2025).

Q 45.2 Thu 11:30 P 3

UV-Compatible Mie Void Metasurfaces — •Serkan Arslan, Julian Schwab, Harald Giessen, and Mario Hentschel — University of Stuttgart, 4th Physics Institute

In recent years, metasurface design has increasingly shifted toward dielectric platforms rather than plasmonic systems. While plasmonic resonances are limited by intrinsic ohmic losses in metal nanostructures, high-refractive-index dielectrics support low-loss Mie resonances in the infrared and visible spectral ranges. However, this advantage diminishes in the ultraviolet (UV), where nearly all dielectric materials become highly absorptive at sufficiently high photon energies. Consequently, UV metasurface research has largely focused on identifying wide-bandgap materials with minimal absorption.

Here, we take a different approach based on Mie void resonances, which have emerged as a complementary concept in dielectric nanophotonics. By confining light in air within a high-refractive-index host, Mie voids circumvent material losses and enable dispersion-free resonance tuning extending into the UV.

We introduce polarization-dependent elliptical Mie voids and investigate their polarization-resolved resonances and mode formation. Exploiting this polarization degree of freedom, we fabricate Pancharatnam-Berry (PB) phase metasurfaces on GaAs substrates. These metasurfaces demonstrate 90° off-axis reflective focusing in the visible range with numerical apertures up to 0.25, as well as orbital angular momentum (OAM) generation.

Q 45.3 Thu 11:45 P 3

A new framework for topological plasmonics — •Julius T. Gohsrich[1,2], Norman S. Israel[3], Lora Ramunno[3], and Flore K. Kunst[1,2] — [1]Max Planck Institute for the Science of Light, Erlangen, Germany — [2]Department of Physics, Friedrich-Alexander Universität Erlangen-Nürnberg, Erlangen, Germany — [3]Department of Physics and Nexus for Quantum Technologies Institute, University of Ottawa, Ottawa, Canada

Plasmonics is the study of the interaction between light and free electrons at metal-dielectric interfaces at the nanoscale. A versatile platform in this field are systems of coupled metallic nanoresonators (MNRs), which are for example used to construct metasurfaces for sensing applications. Topological phenomena can provide novel functionalities to the already rich physics of such structures.

I will present a new framework to analyze the topology of coupled MNRs. Having all relevant properties of the constituent MNRs, the properties of the coupled MNR system are encoded in the solutions of a non-Hermitian eigenvalue problem. Employing our method, we analyze a plasmonic SSH model, and compare our results with full-wave numerics. Our approach allows different approximations, resulting in computational efficiency and scalability compared to full-wave numerics, making it a powerful tool for analyzing topological plasmonic structures and shaping our understanding of these. Beyond that, the presented methods allow for the optimization and design of topological plasmonic nanostructures with potential applications in sensing, microscopy and optical communication.

Q 45.4 Thu 12:00 P 3

Periodic light meets periodic matter — •Frieder Lindel[1,2,3], Carlos J. Sánchez Martínez[1,2], Johannes Feist[1,2], and Francisco García-Vidal[1,2] — [1]Departamento de Física Teórica de la Materia Condensada, Universidad Autónoma de Madrid, Spain — [2]Condensed Matter Physics Center (IFIMAC), Universidad Autónoma de Madrid, Spain — [3]Institute for Theoretical Physics, ETH Zürich, Switzerland

Strong light-matter coupling is a key requirement for many quantum technologies, typically achieved through field enhancement in optical cavities or antennas. It leads to the hybridisation of light and matter excitations into polaritons.

In my talk, the concept of crystal polaritons will be introduced [1], which arise when collective excitations of periodic arrays of quantum emitters are strongly coupled to the light modes supported by a metasurface. We will construct an ab initio few-mode quantization scheme for metasurface resonances based on macroscopic quantum electrodynamics, which provides a framework for analyzing the emergence of strong light-matter coupling in metasurfaces and the formation of crystal polaritons. We will see how the interactions between crystal polaritons lead to single photon nonlinearities for extremely low polariton densities, allowing resonant quantum light generation orders of magnitude higher than in state-of-the-art nonlinear metasurfaces.

[1] F. Lindel, C. J. S. Martínez, J. Feist, F. J. Garcia-Vidal, arXiv preprint: arXiv:2508.00797 (2025).

Q 45.5 Thu 12:15 P 3

Interaction of Structured Light with Nanostructured Matter — •Noah Apostolico, Leander Siegle, Luca Schmid, Tim-Dominik Gómez, Mario Hentschel, and Harald Giessen — 4th Physics Institute and Research Center SCoPE, University of Stuttgart, Pfaffenwaldring 57, 70569 Stuttgart, Germany

Although structured light has been extensively studied, its interaction with nanoscale matter has remained largely unexamined. Here, we demonstrate a symmetry-dependent interaction between structured light and nanostructured absorbers by investigating the orbital-angular-momentum-dependent extinction of gold nanodisk oligomers. Using a rigorous design framework, we fabricate diffractive optical elements via two-photon-polymerization grayscale lithography to generate three distinct flower-like beam modes. Scanning these beams across oligomers of different symmetries reveals that extinction is maximized when the beam and structure share the same rotational symmetry and reduced otherwise. A semi-analytical overlap model reproduces the observed trends with deviations consistently below 10%, confirming the robustness of the symmetry-based interaction mechanism.

Q 45.6 Thu 12:30 P 3

Nanoscale free-electron dynamics in plasmonic nanostructures — •Fabian Scheidler, Jessica Meier, and Bert Hecht — Experimental Physics 5, University of Würzburg, Am Hubland, 97074 Würzburg, Germany

Intense laser pulses give rise to strong-field phenomena, where the external electromagnetic field exceeds the binding field of electrons in matter [1]. At sharp metallic nanotips, this leads to a nonlinear photocurrent driven by multiphoton and strong-field photoemission [2].

Plasmonic nanoantennas fabricated by focused helium ion beam milling from monocrystalline gold microplatelets provide large field enhancements stemming from both an asymmetric nanotip-shaped gap and plasmonic hotspots [3]. Such structures have been shown to yield a geometry-dependent photocurrent across small gaps when driven by a femtosecond Ti:Sa laser in the visible to infrared spectral regime.

Our goal is to employ nanoantenna systems as local electron sources with designed plasmonic near fields for electron control. To describe the free-electron dynamics, we develop a semiclassical simulation scheme to analyze free-electron motion as well as the resulting nonlinear photocurrent.

(1) Dombi, P. et al. Rev. Mod. Phys. 2020, 92, 025003.
(2) Krüger, M. et al. Journal of Physics B: Atomic, Molecular and Optical Physics 2018, 51, 172001.
(3) Meier, J. et al. Advanced Optical Materials 2023, 11, 2300731.

Q 45.7 Thu 12:45 P 3

Near-field metasurfaces for light shaping — •Luca Schmid[1], Julian Schwab[1], Chi Li[2], Kaijian Xing[2], Stefan Maier[2], Harald Giessen[1], Haoran Ren[2], and Mario Hentschel[1] — [1]4th Physics Institute and Research Center SCoPE, University of Stuttgart, Pfaffenwaldring 57, 70569 Stuttgart, Germany — [2]School of Physics and Astronomy, Monash University, Clayton, Victoria, Australia

Plasmonic and dielectric nanophotonic building blocks allow for shaping the flow of light at boundaries and interfaces. They have opened the field of metasurfaces, which until now mostly allow for the creation of nearly arbitrary intensity distributions in the far-field. Drawing inspiration from this concept, we introduce metasurfaces for near-field light shaping. Desired near-field intensity distributions can be created by engineering the distribution of individual scatterers on metallic surfaces and hence the interference of the individually launched surface plasmons. Using this ansatz, we demonstrate metasurfaces which enable to direct, focus, and demultiplex incident light. We implement these structures by a peel-off process from molds, which results in ultra-smooth metallic surfaces, maximizing the plasmon propagation length. Far-field measurements based on a k-space spectroscopy setup allow us to image the local near-field and show excellent agreement with modelling and simulation. We envision that the creation of nearly arbitrary near-field distributions will enable nanoscale routing and sorting of light based on polarization, orbital angular momentum, and wavelength, as well as help realize novel coupling schemes to emitters and nanoscale systems.

Q 46: Open Quantum Systems II

Time: Thursday 11:00–13:00 Location: P 4

Invited Talk Q 46.1 Thu 11:00 P 4

Squeezed Light and Optimal Phase Estimation for Quantum Metrology — •Mojdeh Shikhali Najafabadi[1], Luis L. Sánchez-Soto[2], Joel F. Corney[3], and Gerd Leuchs[1,4] — [1]Max Planck Institute for the Science of Light — [2]Departamento de Óptica, Facultad de Física, Universidad Complutense, 28040 Madrid, Spain — [3]School of Mathematics and Physics, University of Queensland, Brisbane, Queensland 4072, Australia — [4]Institut für Optik, Information und Photonik, Friedrich-Alexander-Universität Erlangen-Nürnberg, 91058 Erlangen, Germany

Quantum metrology has progressed rapidly over the past decade, yet many approaches still rely on idealised models or tightly controlled laboratory conditions that limit their practical relevance. At its core, quantum metrology relies on four key stages -probe preparation, parameter encoding, measurement, and estimation- each of which must be optimised to achieve precision beyond classical limits. In this talk, I focus on some central components of this framework. First, I introduce squeezed states and phase-space approaches, with emphasis on the generation of quantum resources using resonance-based light-matter interactions and Kerr nonlinearities. I present our theoretical study of squeezing mechanisms arising from resonant nonlinear interactions between a coherent optical pulse and an atomic vapour confined within photonic crystal fibres. Finally, I discuss an asymptotically optimal phase-estimation protocol based on Adaptive Quantum State Estimation (AQSE) for squeezed vacuum states and present recent results from our work.

Q 46.2 Thu 11:30 P 4

From lasers to photon Bose–Einstein condensates: A unified description via an open-dissipative Bose–Einstein distribution — •Joshua Krauss, Enrico Stein, and Axel Pelster — Physics Department and Research Center OPTIMAS, RPTU Kaiserslautern-Landau, Kaiserslautern, Germany

Photon condensation was first observed in 2010 within a dye-filled microcavity at room temperature [1] and gained interest since then. In this study we examine how the driven-dissipative nature of a photon Bose–Einstein condensate modifies the condensation process [2]. To this end, we consider a rate-equation model, which can be derived microscopically [3–5]. It depends on external parameters such as emission and absorption rates as well as cavity photon losses [6]. In steady state, the photon occupation follows an open-dissipative Bose–Einstein distribution whose chemical potential is set self-consistently by the dye's ground- and excited-state populations. We show that driven-dissipative parameters strongly alter the distribution and use these results to distinguish photonic condensation from both atomic condensation and lasing [2].

[1] J. Klaers *et alii*, *Nature* **468**, 545 (2010)
[2] J. Krauß *et alii*, *ArXiv:*2510.05917 (2025)
[3] P. Kirton and J. Keeling, *Phys. Rev. Lett.* **111**, 100404 (2013)
[4] M. Radonjić *et alii*, *New J. Phys.* **20**, 055014 (2018)
[5] E. Stein, *PhD. Thesis*, TU Kaiserslautern, (2022)

[6] J. Schmitt *et alii*, *Zenodo*, DOI: 10.5281/zenodo.10852935 (2024)

Q 46.3 Thu 11:45 P 4

Towards an autonomous optomechanical Maxwell Demon engine — •Sander Stammbach und Stefan Nimmrichter — Universität Siegen

We present a fully autonomous model for a mechanical Maxwell demon engine that converts heat absorbed by a qubit into population inversion of an attached quantum battery system. A damped mechanical oscillator acts as a pointer that incorporates the essential demon function of information acquisition about the qubit state and subsequent feedback into the system dynamics, replacing external measurements and control operations. This is achieved by means of the Holstein Hamiltonian, which makes the pointer*s equilibrium position depend on the qubit state and thereby leads to a state-dependent effective resonance shift. The mechanism enables a selective energy transfer to an attached spin system that acts as the quantum battery. We derive both local and global Lindblad master equations for the coupled system and identify the parameter regimes in which the engine operates efficiently. The figure of merit is the resulting steady-state population inversion of the battery, quantified in terms of ergotropy. Based on these results, we discuss the necessary conditions for practical implementations of the demon engine on realistic experimental platforms.

Q 46.4 Thu 12:00 P 4

Dissipative generation of currents by nonreciprocal local and global environments — •Catalin-Mihai Halati — Max Planck Institute for the Physics of Complex Systems, Nöthnitzer Str. 38, 01187 Dresden, Germany

We investigate the mechanisms necessary for the stabilization of complex quantum correlations by exploring dissipative couplings to nonreciprocal reservoirs. We analyze the role of locality in the coupling between the environment and the quantum system of interest, as we consider either local couplings throughout the system, or a single global coupling. We contrast the results obtained for the two scenarios in which a chain of strongly interacting hardcore bosonic atoms is coupled directly to Markovian kinetic dissipative processes, or experiences effective dissipation through the mediation of the field of a lossy optical cavity. To investigate the dissipative dynamics of the many-body quantum systems considered we perform numerical simulations employing matrix product states methods. We show that by coupling atomic tunneling terms to the global field of a dissipative cavity we can stabilize at long times both finite currents and current-current correlations throughout the atomic chain. This is in contrast to the setup in which dissipation acts directly via local tunneling processes, where currents arise in a narrow region of the system and the current-current correlations are rapidly decaying.

Q 46.5 Thu 12:15 P 4

Dissipative loading of ultracold atom tweezer arrays — •Lara Giebeler[1], Alexander Schnell[1], Monika Aidelsburger[2,3,4], and André Eckardt[1] — [1]Institute for Physics and Astronomy, Technical University Berlin — [2]Munich Center for Quantum Science and Technology — [3]Max-Planck-Institut für Quantenoptik — [4]Fakultät für Physik, LMU Munich

Using ultracold atoms in quantum computing and simulation often requires arbitrary single-atom control, typically achieved with optical tweezer arrays. However, defect-free loading of large-scale arrays remains challenging due to the slow speeds and limited loading fidelities of stochastic preparation methods.

To overcome these limitations, in this work we introduce a dissipative scheme for loading atoms into tweezers, mediated by laser-coupled interactions with a fermionic bath. In particular, we explore the trade-off between loading time and fidelity depending on the strength of the system bath coupling and the impact of reservoir size and temperature.

Q 46.6 Thu 12:30 P 4

Time complexity of dissipative quantum search with resetting — •Sayan Roy[1,2], Emma King[1,2], Francesco Mattiotti[2], Markus Bläser[3,4], and Giovanna Morigi[2,4] — [1]Equal contribution — [2]Theoretical Physics, Saarland University, 66123 Saarbrücken, Germany — [3]FR Informatics, Saarland University, 66123 Saarbrücken, Germany — [4]Center for Quantum Technologies (QuTe), Saarland University, Campus, 66123 Saarbrücken, Germany

Searching a database is a central task in computer science and is paradigmatic of transport and optimization problems in physics. For an unstructured search, Grover's algorithm predicts a quadratic scaling of the search time with the database size N, $t_s \sim \sqrt{N}$. Numerical studies suggest that the time complexity t_s can change in the presence of feedback, injecting information during the search. We determine the time complexity of the quantum analog of a randomized algorithm, which implements feedback in its simplest form. The search is a continuous-time quantum walk on a complete graph, where the target is continuously monitored by a detector. Additionally, the quantum state is reset to the initial state if the detector does not click within a specified time interval. This yields a non-unitary, non-Markovian dynamics. We optimize the search time as a function of the hopping amplitude, detection rate, and resetting rate. We identify parameter regimes in which the search time scales as $t_s \sim N^\alpha$ with $\alpha < 1/2$, achieving a time complexity that may surpass the Grover optimal bound.

Q 46.7 Thu 12:45 P 4

Adiabatic steering and entanglement generation using dissipative quantum systems — •Keshav Venkataraman[1,2,3], Adrian Parra-Rodriguez[1,2,3], Marko Ljubotina[2,3], and Peter Rabl[1,2,3] — [1]Walther-Meißner-Institut, Bayerische Akademie der Wissenschaften, 85748 Garching, Germany — [2]Physics Department, Technical University of Munich, TUM School of Natural Sciences, Lichtenbergstr. 4, 85748 Garching, Germany — [3]Munich Center for Quantum Science and Technology (MCQST), Schellingstr. 4, 80799 München, Germany

Adiabaticity represents one of the most versatile tools to engineer quantum states of a coherent system, but these schemes typically require large run-times to achieve high fidelities. Various "Shortcuts to Adiabaticity" have been proposed to counteract these losses, to carry out adiabatic sweeps faster than uncontrolled dissipation processes. When the family of target states is known, a new scheme called "Leakage minimization"(PRX Quantum 3, 030343 (2022)) can be used to optimize either the path taken by the tunable parameter or the time-varying amplitudes of auxilliary control fields required to minimize non-adiabatic losses.

This talk focuses on extending this scheme to the dissipative regime, using the steady state entanglement generation protocol of Phys. Rev. A 91, 042116. Such schemes generically involve trade-offs between the entanglement content of the final dark state and its relaxation time (PRX Quantum 5, 040305). Adiabatic manipulations, in contrast, can generate highly entangled states much quicker.

Q 47: Quantum Technologies – Sensing II

Time: Thursday 11:00–13:00 Location: P 5

Q 47.1 Thu 11:00 P 5

Advancing geophysical research using optically pumped magnetometers — •Marco Decker[1,2], Rafael Rothganger de Paiva[1,3], Raquel Flores[1], Dimitrii Grigorev[1], and René Reimann[1] — [1]Quantum Research Center, Technology Innovation Institute, Abu Dhabi, UAE — [2]Department of Physics and Research center OPTIMAS, RPTU University Kaiserslautern-Landau — [3]Universidade Federal do ABC, Santo Andre, Sao Paulo, Brazil

Highly precise and accurate magnetic field sensing has real-world applications in biomedical imaging [1], positioning and navigation [2]. In this work, we present the magnetic analysis of rock samples without remanent magnetization using optically pumped magnetometry, opening applications in paleomagnetic research and geological exploration [3]. The core samples are placed inside a shielded environment with a known, uniform static magnetic field of up to 5 mT. Utilizing a commercial SERF magnetometer, we measure the samples magnetic susceptibillity with pT precision and millimeter-scale resolution. The setup is characterized with well-known test samples and then tested with real-world limestone samples. Linear and rotational translation enable the scanning of 2D cylindrical surface maps of the magnetic field, which can then be used to infer the samples internal magnetic properties. The analyzed data is in general accordance with dipole simulations, also confirming clear limitations of the setup.

[1] P. K. Mandal, Front. Comput. Neurosci. 12 (2018); [2] M. Muradoglu, arXiv, 2504.08167 (2025); [3] C. Deans, Appl. Opt. 57, 2346-2351 (2018)

Q 47.2 Thu 11:15 P 5

The boundary time crystal as a light source for quantum enhanced sensing beyond the heisenberg limit — •Malik Jirasek[1], Igor Lesanovsky[1,2], and Albert Cabot[3] — [1]Universität Tübingen, Tübingen, Germany — [2]University of Nottingham, Nottingham, United Kingdom — [3]Universitat de les Illes Balears, Palma de Mallorca, Spain

Modern precision measurements, such as interferometry for detecting gravitational waves, rely on the estimation of optical phases encoded in light fields. We propose to exploit the collectively enhanced output field of a driven-dissipative many-body open quantum system as a light source in order to improve the precision of estimating optical phases [1]. These systems can generate emission patterns that are drastically different than those of conventional sources, for example lasers. For instance, the output fields of time crystals can exhibit intricate time-correlations. We find, that these benefit the sensitivity of measurement protocols for phase shifts, which we show theoretically by employing a boundary time crystal (BTC) as a light source. The fundamental bound on the precision of such estimation shows scaling with system size of the BTC that surpasses the Heisenberg limit. This scaling can be partially harnessed by a protocol, in which the phase shifted light field is guided into an auxiliary replica system, which serves as a detector that is sensitive to non-trivial temporal correlations of the light.

[1] M. Jirasek, *et al.*, arXiv:2511.23416 (2025)

Q 47.3 Thu 11:30 P 5

Part 1: Optically Addressable Molecular Spins at 2D surfaces — •YanTung Kong, XuanKai Zhou, Cheuk Kit Cheung, Ruoming Peng, and Jörg Wrachtrup — 3. Physikalisches Institut, University of Stuttgart, 70569 Stuttgart, Germany

Optically addressable surface spins constitute a long-sought goal in quantum sensing, offering a pathway to probe quantum phenomena with atomic-scale precision. Here, we introduce a novel architecture in which pentacene spin molecules are anchored onto two-dimensional hexagonal boron nitride (hBN) and self-align with the underlying lattice. This configuration yields robust optically detected magnetic resonance (ODMR) signals from 4 K to room temperature. We further demonstrate ensemble spin sensing of Fe3GaTe2 (FGT), as well as controlled positioning of Pc molecules. This work represents the first demonstration of a surface molecular spin sensor that integrates long coherence, optical addressability, and interfacial functionality, thereby enabling quantum sensing capabilities beyond those of conventional solid-state spin systems.

Q 47.4 Thu 11:45 P 5

Nanodiamond surface chemistry for improved quantum coherence in zero-field — •Tulika Agrawal for the AK Weil MPIP-Collaboration — Max Planck Institute for Polymer Research, Mainz, Germany

Nitrogen vacancy (NV) in diamond results in the application of diamond in quantum technologies such as sensing, computing and navigation. This is possible due to the sublevels of NV center which can be manipulated with microwave/RF and yet optically detectable. NV center has been proven to be a promising candidate due to their long coherence times (T2) at room temperature. However, the T2 times of NVs suffer drastic reduction when they are in nanodiamonds (NDs) instead of bulk diamond. Moreover, NDs are functionalized with a variety of chemical groups to make them compatible for desired application. This surface modification can cause a significant impact on T2 times of NV centers. Therefore, it has become crucial to investigate deeper into the relationship between surface chemistry and T2 times. In this work, T2 times have been investigated in two types of functionalized NDs, nanogel coated NDs (NDNG) and polyglycerol coated NDs (NDPG). To obtain T2 times in zero magnetic field, two different pulse sequences, Hahn-echo and geometric spin, have been employed. While the conventional EPR study has shown a reduction in surface spin noises upon functionalization, T2 measurements have distinctly shown the change in T2 times from NG to PG.

Q 47.5 Thu 12:00 P 5

Magnetic Field Imaging in SiC Quantum Microscope — •Ayisha Suhana[1,2], Tatiana A. U Svetikova[1,2], Christoph Schneider[1], Manfred Helm[1,2], Andrei N Anisimov[1], and Georgy V Astakhov[1] — [1]Helmholtz-Zentrum Dresden-Rossendorf, Dresden, Germany — [2]Technische Universitat Dresden, Dresden, Germany

Studying neuronal activity requires detecting ultra-weak, dynamic magnetic fields generated by neural electrical signals. Quantum sensors based on spin defects, specifically NV centers in diamond, have demonstrated applications from action-potential detection to battery-current monitoring and geological mapping. These advances motivate the exploration of wide-bandgap semiconductors, such as silicon carbide (SiC) and hexagonal boron nitride for scalable quantum sensing.

We used silicon vacancy centers in SiC for wide-field magnetic imaging using optically detected magnetic resonance with dual-frequency, microwave-free [1], and time-resolved sensing protocols. The magnetic fields from continuous and pulsed currents in a wire beneath the sample are reconstructed using a Python-based workflow. The quantum silicon carbide microscope achieves a 50 * 50-pixel field of view with 30 *m spatial and 50 ms temporal resolution, enabling magnetic field imaging in current-carrying structures [2], with potential applications in biomedical research.

[1] D. Simin et al., Phys. Rev. X 6, 031014 (2016) [2] A. Suhana et al., arXiv:2509.14888 (2025)

Q 47.6 Thu 12:15 P 5

High-Sensitivity NV-Diamond Magnetometry for Non-Invasive Detection of Magnetocardiography — •Michael Kübler, Jixing Zhang, Magnus Benke, Yi hua Wang, Cheuk Cheung, and Andrej Denisenko — 3rd Institute of Physics, University of Stuttgart, 70569 Stuttgart, Germany

We demonstrate detection of weak cardiac magnetic signals using high-sensitivity NV-diamond magnetometers enhanced by magnetic flux concentrators and CW-ODMR readout. With this scheme, we achieve effective sub-pT sensitivity and reliably detect temporal fluctuations corresponding to the propagation of cardiac action potentials. The signals show close agreement with conventional electrophysiology electrodes, but without direct tissue contact.

This method enables non-invasive and high-resolution monitoring of the heart's electrical activity, offering potential for early diagnosis and continuous real-time monitoring of cardiovascular health. These results highlight NV-diamond magnetometry as a promising platform for biomedical applications, bridging quantum sensing and clinical diagnostics, and supporting future integration into wearable devices for arrhythmia detection and other cardiovascular disorders.

Q 47.7 Thu 12:30 P 5

Calibrated Generation of Heralded Single Photons — •Daniel Borrero Landazabal and Kaisa Laiho — German Aerospace Center (DLR), Institute of Quantum Technologies, Wilhelm-Runge-Str. 10, 89081 Ulm, Germany

Heralded single-photon sources based on parametric down-conversion (PDC) are indispensable in many quantum sensing applications. To characterize such emitters conventionally the second-order correlation function $g_{\mathrm{h}}^{(2)}$ of the heralded state has been used. However, the practical deployment of such sources demands a more rigorous, loss-tolerant characterization. We employ a waveguided type-II PDC process pumped by a pulsed laser, generating orthogonally polarized photon pairs with a low optical mode number. After separating the photon pairs–signal and idler– from each other, the detection in idler with a superconducting nanowire single-photon detector heralds the target state in signal. By recording counts of coincidences and singles, we measure $g_{\mathrm{h}}^{(2)}$ and extract loss-tolerantly the mean photon number and photon-number parity with a high accuracy. The former delivers access to the residual multiphoton contamination, while the latter provides a direct measure of the non-classicality of the heralded states. We demonstrate that these figures of merit provide a stringent benchmark for a high-quality single-photon generation, surpassing the information delivered by $g_{\mathrm{h}}^{(2)}$ alone. Our results pave the way for the generation of calibrated single-photon probes and may find usage for example in quantum radiometry to achieve precision in quantum optics experiments.

Q 47.8 Thu 12:45 P 5

Multiparametric sensing with the nitrogen-vacancy color center in diamond — •Leon Advena[1], Tofianme Sorgwe[1], Florian Sledz[1], Mario Agio[1,2], and Assegid Mengistu Flatae[1] — [1]Laboratory of Nano-Optics, University of Siegen, 57072 Siegen, Germany — [2]National Institute of Optics (INO), National Research Council (CNR), 50125 Florence, Italy

Modern sensing applications increasingly require the simultaneous measurement of multiple physical parameters with high sensitivity. Nitrogen-vacancy centers in diamond present a promising solution to the various challenges associated with multiparametric sensing applications. These atomic-scale defects can be optically initialized, manipulated, and read out via laser excitation using optically detected magnetic resonance (ODMR). They are capable of operation under ambient and harsh conditions. Here, we demonstrate a simultaneous and internally cross-validated sensing platform capable of detecting both magnetic fields and temperature with sensitivities of around 500 $nT/\sqrt{Hz}$ and 10 $mK/\sqrt{Hz}$, respectively. Our method integrates ODMR, zero-phonon line (ZPL) spectral shifts, and linewidth broadening, each providing independent spectral signatures sensitive to distinct physical effects. This approach enhances measurement precision, enables internal consistency checks, and decouples intertwined phenomena such as temperature-induced variations in magnetization. The demonstrated technique significantly expands the functional capabilities of NV-based sensors, advancing their potential for high-precision metrology in complex environments.

Q 48: QuanTour IV – Building Blocks

Inspired by QuanTour, the traveling quantum-dot light source, the sessions QuanTour I-V focus on the physics of quantum light generation in solid-state systems and applications in quantum networks.

Time: Thursday 11:00–13:00 Location: P 7

Invited Talk Q 48.1 Thu 11:00 P 7

Quantum teleportation with remote quantum dots in a metropolitan hybrid quantum network — A. Laneve[1], G. Ronco[1], M. Beccaceci[1], F. Salusti[2], N. Claro-Rodriguez[2], G. De Pascalis[1], E. Schöll[2], L. Hanschke[4], T. M. Krieger[3], Q. Buchinger[5], S. F. Covre da Silva[6], S. Stroj[7], S. Höfling[5], T. Huber-Loyola[8], M. A. Usuga Castaneda[9], G. Carvacho[1], N. Spagnolo[1], •M. B. Rota[1], F. Basso Basset[10], A. Rastelli[3], F. Sciarrino[1], K. D. Jöns[2], and R. Trotta[1] — [1]Sapienza Università di Roma, Italy — [2]Paderborn University, Germany — [3]Johannes Kepler University, Austria — [4]Technical University of Munich, Germany — [5]University of Würzburg, Germany — [6]Universidade Estadual de Campinas, Brazil — [7]Vorarlberg University of Applied Sciences, Austria — [8]Karlsruhe Institute of Technology, Germany — [9]Single Quantum B.V., Delft, The Netherlands — [10]Politecnico di Milano, Italy

We demonstrate the first all-photonic quantum teleportation protocol using dissimilar semiconductor quantum dot (QD) emitters, deployed in a hybrid fiber + free-space metropolitan link. Two independent GaAs quantum dots, engineered via nanophotonic cavities, piezoelectric strain tuning and magnetic-field control, serve as the sender and entangled-photon source. The emitters are initially spectrally distinct, through tailored tuning we surpass the classical fidelity limit more than ten standard deviations (0.82(1)). This successful demonstration constitutes a key step toward scalable, QD-based quantum relays and repeaters.

Q 48.2 Thu 11:30 P 7

Full photonic quantum teleportation with remote quantum dots — •Simone Luca Portalupi[1], Tim Strobel[1], Michal Vyvlecka[1], Ilenia Neureuther[1], Tobias Bauer[2], Marlon Schäfer[2], Stefan Kazmaier[1], Nand Lal Sharma[3], Raphael Joos[1], Jonas H. Weber[1], Cornelius Nawrath[1], Weijie Nie[3], Ghata Bhayani[3], Caspar Hopfmann[3], Christoph Becher[2], and Peter Michler[1] — [1]Institut für Halbleiteroptik und Funktionelle Grenzflächen, Center for Integrated Quantum Science and Technology (IQST) and SCoPE, University of Stuttgart, Stuttgart, Germany — [2]Fachrichtung Physik, Universität des Saarlandes, Saarbrücken, Germany — [3]Institute for Integrative Nanosciences, Leibniz IFW Dresden, Dresden, Germany

The realization of a multinode quantum network is the first necessary step towards the implementation of the quantum internet. With this target in mind, we will report on a recent experiment where successful full-photonic quantum teleportation has been achieved, employing two remote quantum dots as sources of quantum light. This experiment exploited quantum frequency conversion to enable operation at telecom wavelength. [1] The successful teleportation achieved with two distinct sources lay the foundation to future experiments: it shows scalability of this approach, compatibility with fibre networks, interoperability of different systems (as semiconductor quantum dots and frequency conversion elements), and operation of distinct nodes. All are necessary steps towards the implementation of a realistic quantum network.

[1] T. Strobel, et al., Nat. Commun. 16, 10027 (2025).

Q 48.3 Thu 11:45 P 7

AlGaAs nanowires as a universal platform for GaAs, InGaAs, and InAs quantum dots — •Rohan Radhakrishnan[1], Rodion Reznik[2], Gilles Patriarche[3], George Cirlin[2], and Nika Akopian[1] — [1]DTU Department of Electrical and Photonics Engineering, Technical University of Denmark, 2800 Kongens Lyngby, Denmark — [2]St. Petersburg, Russia — [3]Centre de Nanosciences et Nanotechnologies, Université Paris Saclay, CNRS, 91120 Palaiseau, France

Optical quantum dots are at the core of quantum communication and quantum photonic technologies, requiring precise control over emission wavelengths spanning from 780 nm to 1.55 μm. However, no existing host material enables the full compositional tuning needed to cover the range from GaAs through InGaAs to InAs quantum dots. Here, we demonstrate that embedding InGaAs quantum dots in AlGaAs nanowires provides a universal platform capable of spanning this entire spectral range. By growing 2 s and 5 s long sections of InGaAs, we form quantum dots emitting at 780 nm and 920 nm, respectively, showcasing control of emission wavelength via growth parameters. Unlike previous systems, our approach offers continuous compositional control without compromising optical quality, establishing AlGaAs nanowires as a versatile host for scalable, high-performance quantum light sources.

Q 48.4 Thu 12:00 P 7

Universal super-resolution framework for imaging of quantum dots — Dominik Vašinka[1], Jaewon Lee[2], •Charlie Stalker[2], Victor Mitryakhin[3], Ivan Solovev[3], Sven Stephan[3,4], Sven Höfling[5], Falk Eilenberger[6,7,8], Seth Ariel Tongay[9], Christian Schneider[3], Miroslav Ježek[1], and Ana Predojević[2] — [1]Department of Optics, Faculty of Science, Palacký University, 17. listopadu 12, 77900 Olomouc, Czechia — [2]Department of Physics, Stockholm University, 10691 Stockholm, Sweden — [3]Institut of Physics, University of Oldenburg, D-26129 Oldenburg, Germany — [4]University of Applied Sciences Emden/Leer, 26723 Emden, Germany — [5]Technische Physik, Physikalisches Institut and Würzburg-Dresden Cluster of Excellence ct.qmat, Universität Würzburg, Am Hubland, D-97074 Würzburg, Germany — [6]Institute of Applied Physics, Abbe Center of Photonics, Friedrich Schiller University Jena, 07743 Jena, Germany — [7]Fraunhofer-Institute for Applied Optics and Precision Engineering IOF, 07743 Jena, Germany — [8]Max-Planck-School of Photonics, 07743 Jena, Germany — [9]Materials Science and Engineering, School for Engineering of Matter, Transport, and Energy, Arizona State University, Tempe, Arizona 85287, United States

We present a universal deep-learning method that reconstructs super-resolved images of quantum emitters from a single camera frame measurement. This method was then validated experimentally on various quantum dot samples and allows for rapid super-resolution for quantum photonic device fabrication.

Q 48.5 Thu 12:15 P 7

Quantum communication protocols with Quantum Dots as a source of Polarization-entangled photons — Michele Rota[1], Francesco Basso Basset[1,2], Alessandro Laneve[1], •Francesco Salusti[3], Nicolas Claro Rodriguez[3], Giuseppe Ronco[1], Mattia Beccaceci[1], Tobias M. Krieger[4], Quirin Buchinger[5], Saimon F. Covre da Silva[6], Sandra Stroj[7], Mariia Gumberidze[8], Vladyslav Usenko[8], Sven Höfling[5], Tobias Huber-Loyola[5,9,10], Mario A. Usuga Castaneda[11], Armando Rastelli[4], Klaus D. Jöns[3], and Rinaldo Trotta[1] — [1]Department of Physics, Sapienza University of Rome, Rome, Italy — [2]Dipartimento di Fisica, Politecnico di Milano, Milano, Italy — [3]PhoQS Institute, CeOPP, and Department of Physics, Paderborn University, Paderborn, Germany — [4]Institute of Semiconductor and Solid State Physics, Johannes Kepler University, Linz, Austria — [5]Technische Physik, University of Würzburg, Würzburg, Germany — [6]Universidade Estadual de Campinas, Instituto de Fisica Gleb Wataghin, Campinas, Brazil — [7]Research Center for Microtechnology, Vorarlberg University of Applied Sciences, CAMPUS V, Dornbirn, Austria — [8]Department of Optics, Palacký University, Olomouc, Czech Republic — [9]Institute of Photonics and Quantum Electronics, Karlsruhe Institute of Technology, Karlsruhe, Germany — [10]Center for Integrated Quantum Science and Technology (IQST), Karlsruhe Institute of Technology, Karlsruhe, Germany — [11]Single Quantum B.V., Delft, The Netherlands

We demonstrate entanglement swapping exploiting a quantum dot in a cavity, using entangled photons for a modified Ekert91 protocol.

Q 48.6 Thu 12:30 P 7

Mode-engineering in quantum dot single photon sources to increase collection and excitation efficiency — •Samuel Huber[1], Albert Adiyatullin[2], Viviana Villafane[2], Dario A. Fioretto[1], Sebastien Boissier[2], Huong Thi Au[2], and Pascale Senellart[1] — [1]C2N, Palaiseau, France — [2]Quandela, Massy, France

The development of photonic quantum technologies requires high quality single photon sources in terms of brightness, purity, and indistinguishability. In my PhD, I aim to improve these metrics in micropillar quantum dot single photon sources by studying the optical eigenmodes in the micropillar. The eigenmodes spatial overlap with the mode of the collection path directly contributes to the single photon source brightness. Quantifying this coupling efficiency also reveals new pathways to enhance the efficiency of detuned quantum dot excitation protocols. Standard detuned-pulse schemes are fundamentally constrained by the micropillar stopband, which suppresses field penetration into the cavity mode, increasing the required excitation power. To mitigate this limitation, I am exploring the coupling of the detuned pulses to higher-order cavity modes, as well as to auxiliary modes engineered through additional spacer layers within the Bragg-mirror stack. These engineered modes provide improved spectral overlap and field confinement for off-resonant driving, enabling a viable route towards high-efficiency Swing-Up (SUPER) excitation in micropillar resonators.

Q 48.7 Thu 12:45 P 7

Decoy-state quantum key distribution over 227 km with a frequency-converted telecom single-photon source — •Frederik Brooke Barnes[1], Robert Gonzalez-Pousa[2], Christopher L. Morrison[1], Zhe Xian Koong[1], Joseph Ho[1], Francesco Graffitti[1], John Jeffers[2], Daniel K. L. Oi[2], Brian D. Gerardot[1], and Alessandro Fedrizzi[1] — [1]Institute of Photonics and Quantum Sciences, School of Engineering and Physical Sciences, Heriot-Watt Univer- sity, Edinburgh, EH14 4AS, UK — [2]SUPA Department of Physics, University of Strathclyde, Glasgow, G4 0NG, UK

We implement a decoy-state quantum key distribution scheme using a quantum dot frequency-converted to the telecom C-band. The decoy states are created by varying the optical excitation of the quantum emitter to modulate the photon number distribution. We provide an analysis of our scheme based on existing security proofs, allowing the calculation of secret key rates including finite key effects. This enables us to demonstrate, with a realistic single-photon source, positive secret key rates using our scheme over 227~km of optical fibre, equivalent to an increase in loss tolerance greater than one order of magnitude compared to non-decoy schemes, and within 2dB of the tolerable loss when using a single-photon source with similar brightness but perfect single-photon purity. We provide a short perspective on how our methods could be applied to other quantum communication protocols, such as those compatible with quantum memories, to extend secure transmission distances beyond the repeater-less limit.

Q 49: Quantum Communication, Networks, Repeaters, & QKD I

Time: Thursday 11:00–13:00 Location: P 10

Q 49.1 Thu 11:00 P 10

Optical quantum storage of cold atomic ensemble mediated by light-induced fictitious magnetic field — Liang Dong[1], Linyu Chen[1], Xingchang Wang[1], Xinyun Liang[1], •Ying Zuo[2], Georgios Siviloglou[2,3], and JieFei Chen[1,2] — [1]Department of Physics, Southern University of Science and Technology, Shenzhen 518055, China — [2]International Quantum Academy, Shenzhen 518048, China — [3]Department of Physics, University of Crete, Heraklion, Greece

Optical quantum memory is a critical component in quantum computing, sensing, and communication. A major obstacle limiting practical quantum memory based on cold atomic ensemble is the reduced storage lifetime caused by spatiotemporal inhomogeneity in ambient magnetic fields along the elongated atomic cloud. To address this challenge, we demonstrate a method to prolong the storage lifetime of single-photon quantum states using a combination of optically induced virtual magnetic fields and DC bias field. By precisely tailoring the polarization, spatial distribution, and temporal waveform of the AC Stark beam, the generated virtual magnetic field compensates in real-time for spatial inhomogeneities and temporal fluctuations. This high-speed, high-spatial-resolution compensation technique overcomes the limitations of conventional current-coil methods, such as slow response and low spatial resolution, effectively suppressing decoherence in magnetically sensitive quantum states. Furthermore, we propose a scheme for storing time-bin entangled photon pairs prepared at two distinct time bins.

Q 49.2 Thu 11:15 P 10

Towards a spin-exchange collision-based optical quantum memory in noble-gas spins — •Alexander Erl[1,2], Norman Vincenz Ewald[1,2], Andrés Medina Herrera[2], Denis Uhland[3], Wolfgang Kilian[2], Jens Voigt[2], Ilja Gerhardt[3], and Janik Wolters[1,4] — [1]DLR, Institute of Space Research, Berlin — [2]PTB, 8.2 Biosignals, Berlin — [3]LUH, Institute of Solid State Physics, Hannover — [4]TUB, Institute of Physics and Astronomy, Berlin

A critical limitation on current room-temperature quantum memory systems [1] is the maximum achievable storage time on the order of a few μs, which must be extended for various quantum communication applications. We report on our first steps towards a long-lived quantum memory with an all-optical interface based on a mixture of ^{129}Xe noble gas and ^{133}Cs alkali metal vapor, both confined in a glass cell at near room temperature. The interface relies on EIT, implemented through a Λ-scheme in the Zeeman sublevels of the long-lived hyperfine ground states of ^{133}Cs, coupled to an excited state via the D_1 line at 895 nm [2]. A sufficiently long-lived Cs spin coherence is essential for entering the strong spin-exchange coupling regime, where collisions can efficiently transfer the stored quantum excitation from the alkali vapor to the noble-gas ensemble [3]. The coherence time of ^{129}Xe, which can extend up to several hours [4], offers the potential for long-term storage of quantum information in collective atomic excitations. [1] M. Jutisz et al., Phys. Rev. Applied 23, 024045 (2025); [2] G. Buser et al., PRX, 020349 (2022); [3] O. Katz et al., PRA 105, 042606 (2022); [4] C. Gemmel et al., EPJ D 57, 303-320 (2010)

Q 49.3 Thu 11:30 P 10

Exploring the nuclear spin environment of individual erbium emitters — Alexander Ulanowski, Olivier Kuijpers, Benjamin Merkel, Adrian Holzäpfel, •Noah Weinhold, and Andreas Reiserer — Technical University of Munich, TUM School of Natural Sciences, Physics Department and Munich Center for Quantum Science and Technology (MCQST), 85748 Garching, Germany

Nuclear spins in solids exhibit exceptional coherence times and present promising candidates for nuclear spin registers and robust quantum memories. In this work, we focus on the nuclear spin of ^{167}Er dopants, which feature an optical transition within the low-loss wavelength window of optical fibers. Using a high-finesse cryogenic Fabry-Perot cavity, we achieve all-optical control and readout of ^{167}Er dopants in a 10 μm thin yttrium orthosilicate crystal. We further implemented spectroscopy techniques to characterize the superhyperfine interaction with Y nuclear spins surrounding individual Er dopants [1]. This may be used as a resource in quantum technology e.g. enabling the entanglement of nuclear spins with emitted photons or targeting nearby nuclear spins for quantum memories.

[1] A. Ulanowski, O. Kuijpers, B. Merkel, A.Holzäpfel, and A. Reiserer, PRX Quantum 6, 020344 (2025)

Q 49.4 Thu 11:45 P 10

Characterization of Pulsed Entangled Photon Emission via SFWM in Warm Rubidium Vapors — •Giorgio De Pascalis[1], Ioannis Caltzidis[1], Ruben Kampel[1], Shane Andrewski[2], Mael Flament[2], Alexander N. Craddok[2], Sonja Barkhofen[1], Mehdi Namazi[2], and Klaus D. Jöns[1] — [1]Institute for Photonic Quantum Systems (PhoQS), Center for Optoelectronics and Photonics Paderborn (CeOPP) and Department of Physics, Paderborn University, Paderborn, Germany — [2]Qunnect Inc, Brooklyn, USA

The development of robust sources capable of reliably emitting entangled photon pairs-compatible with both current communication systems and emerging quantum devices-is of paramount importance for quantum information applications [1,2]. Practical implementations in deployed quantum networks require both high emission rates and high state fidelity. Spontaneous four-wave mixing (SFWM) has emerged as a promising technique to use in a real telecommunication network [3]. Typically, these sources are driven using continuous-wave coupling and pump fields, a configuration that limits the possibility of controlled synchronized quantum network protocols. We present a comprehensive characterization of the source's emission properties, combining theoretical modeling and experimental measurements, including a CHSH measurement and quantum state tomography of the generated entangled photon pairs. [1] Yin, J. et al. Nature 582, 501-505 (2020) [2] Bennett C. H. et al. Phys. Rev. Lett. 68, 557 (1992) [3] M. Sena et al. arXiv: 2504.08927 [quant-ph]

Q 49.5 Thu 12:00 P 10

What can the experimentalist learn from Bell polytopes? — •Tom Hobbs and Ilja Gerhardt — light & matter group, Institute for Solid State Physics, Leibniz University Hannover, Appelstrasse 2, D-30167 Hannover, Germany

Measurements on entangled systems can produce correlations which are stronger than those predicted by local theories of physics. For a particular experimental configuration, the set of outcomes allowed by local models forms a Bell polytope. Meanwhile, quantum theory allows for a larger outcome set, comprising the whole local polytope plus additional nonlocal correlations. For applications such as quantum key distribution (QKD) or randomness generation, it is important to know whether the measured correlations lie inside or outside the local region. This is typically done by checking if the correlations violate a particular Bell inequality.

In our work we investigate how experimental flaws, such as imperfect state preparation, detector noise, and mismatched measurement bases, affect the set of correlations that can be measured. We show how these correlations can be visualized, and how varying the experimental settings can move the measured correlations inside or outside the Bell polytope. We aim to link our results to a practical entanglement-based QKD scenario.

Q 49.6 Thu 12:15 P 10

Purcell-Enhanced Er^{3+} Dopants in Silicon Nanophotonics for Quantum Networks — •Francesca Molteni, Andreas Gritsch, Jakob Pforr, Benedikt Braumandl, Alexander Ulanowski, Arantza Pineda Gonzalez, and Andreas Reiserer — Technical University of Munich, TUM School of Natural Sciences, Physics Department and Munich Center for Quantum Science and Technology (MCQST), James-Franck-Straße 1, 85748 Garching, Germany

Erbium in silicon provides a promising route towards scalable quantum networks, offering telecom-band emission compatible with low-loss fibers and narrow transitions [1], while enabling the integration of quantum emitters into photonic circuits [2].

We investigate Er^{3+} dopants in a silicon-on-insulator platform, where on-chip photonic crystal cavities produce strong Purcell enhancement via high Q factors and sub-wavelength mode volumes. This enables fast spin initialization and optical single-shot readout [3].

Optical coherence is probed through Rabi oscillations and photon-echo measurements, revealing coherence times exceeding 80% of the lifetime limit and interference of sequentially emitted photons demonstrates high indistinguishability. We will present recent advances that allow for increased Purcell enhancement factors.

These results establish erbium in silicon as a highly promising and scalable platform for future quantum network architectures.

[1] Reiserer, Rev. Mod. Phys. 94, 041003 (2022); [2] Gritsch et al., Phys. Rev. X 12 (4), 041009 (2022); [3] Gritsch et al., Nat. Commun. 16, 64 (2025).

Q 49.7 Thu 12:30 P 10

Shot-noise limited discrete QAM signals for airborne quantum communication — Stefan Richter[1,2], •Hüseyin Vural[1,2], Thomas Dirmeier[2,1], Sheng-Hsuan Huang[1,2], and Christoph Marquardt[1,2] — [1]Chair of optical quantum technologies, Friedrich-Alexander- Universität Erlangen-Nürnberg, Erlangen — [2]Max Planck Institute for the Science of Light, Erlangen

To ensure continuity of operation in quantum communication networks when terrestrial fiber links are (temporarily) unavailable, methods to quickly (re-)establish secure links between access nodes are required. One promising approach is the deployment of airborne mobile nodes to bridge outages and extend secure connectivity. As part of the German QuNET initiative, such a scenario was investigated using a flying transmitter aboard a research aircraft of the German DLR and an optical ground station (OGS) operated by Fraunhofer IOF during two measurement campaigns in April and October 2025 in Erlangen.

Here, we report on our transmitter system and its deployment for testing the feasibility of continuous-variable (CV) QKD over such a dynamic free-space link. Our system is capable of generating discrete quadrature amplitude modulation (QAM) of coherent states required for CV-QKD protocols under the restrictive conditions of a flying platform, while the receiver is connected via fiber to the OGS. Our findings indicate the feasibility of CV-QKD in this harsh environment and over a strongly fluctuating link by successfully exchanging shot-noise-limited signals.

Q 49.8 Thu 12:45 P 10

Non classicality in frequency multiplexed quantum networks — •Theresa Keuter, Patrick Folge, Abhinandan Bhattacharjee, Benjamin Brecht, and Christine Silberhorn — Paderborn University, Integrated Quantum Optics, Institute for Photonics Quantum Systems (PhoQS), Warburger Str. 100

Linear optical quantum networks are a key building block for many quantum technologies, such as Gaussian Boson Sampling. However, previous implementations based on spatial encoding are difficult to scale. We propose a new system, which operates on modes of different frequencies. By employing a dispersion-engineered sum-frequency generation (SFG) process, interactions between these frequency modes can be mediated, enabling a fully programmable, frequency-encoded quantum network within a single spatial and polarization mode. Quantum input states for this network are provided by the strong frequency entanglement of a type-0 parametric down-conversion (PDC) source. In this work, we investigate signatures of non-classicality in such systems as an essential step toward assessing their quantum properties.

Q 50: Matter Wave Interferometry and Metrology II

Time: Thursday 11:00–13:00 Location: P 11

Q 50.1 Thu 11:00 P 11

Quantum Metrology of Spin Sensing with Free Space Electrons — Santiago Beltran Romero[1], •Michael Gaida[2], Philipp Haslinger[1], Dennis Rätzel[1], and Stefan Nimmrichter[3] — [1]Atominstitut, Technische Universität Wien, Stadionallee 2, 1020 Vienna, Austria — [2]Institute for Complex Quantum Systems and Center for Integrated Quantum Science and Technology, Ulm University, Albert-Einstein-Allee 11, 89069 Ulm, Germany — [3]Naturwissenschaftlich-Technische Fakultät, Universität Siegen, Walter-Flex-Str. 3, 57068 Siegen, Germany

Advances in transmission electron microscopy (TEM) are bringing single-spin-sensitive spin-resonance spectroscopy within reach. We analyze the quantum precision limits for sensing magnetic moments with free-electron probes using a scattering model of an electron wavepacket interacting with a localized spin. We study two tasks: estimating the magnitude of a magnetic moment and detecting the presence of a spin. For estimation, we compare the classical Fisher information for typical measurements with the quantum limit and find that standard TEM imaging can saturate this bound when probe backaction is negligible. When backaction is significant, measuring the electron's orbital angular momentum can offer higher sensitivity. Our results establish the quantum limits of spin sensing in TEM and guide the design of experiments targeting individual electron spins or nanoscale nuclear-spin ensembles.

Q 50.2 Thu 11:15 P 11

Optimal Ramsey protocols employing QND-squeezed states — •Maja Scharnagl[1] and Klemens Hammerer[1,2] — [1]Institute for theoretical physics, Leibniz Universität Hannover, Germany — [2]Institute for theoretical physics, Universität Innsbruck, Austria

We investigate quantum non-demolition (QND) measurements and their application in Ramsey protocols. In doing so, we optimize the axes of signal imprint and measurement and perform clock simulations for comparing the optimized protocols to QND-protocols with feedback, aligning the squeezed state with the equator of the Bloch sphere. We include individual and collective dephasing in our description and minimize the analytically calculated Allan deviation of these protocols over the QND-squeezing-strength.

Q 50.3 Thu 11:30 P 11

An industrial single-ion optical frequency standard with a systematic uncertainty below 2×10^{-17} — Axel Friedenauer[1], •Pierre Thoumany[1], Christoph Tresp[1], Daniel Heinrich[1], Saaswath Jeyalathaa Karthikeyan[2], Burghardt Lipphardt[2], Nils Huntemann[2], Stephan Ritter[1], and Jürgen Stuhler[1] — [1]TOPTICA Photonics SE, Gräfelfing, Germany — [2]Physikalisch-Technische Bundesanstalt, Braunschweig, Germany

Rapid advances in research on optical frequency standards (OFS) have enabled ultra-precise instruments and plans for a redefinition of the second. While most of the current OFS are highly specialized laboratory systems, development of commercially available optical clocks that are robust and transportable with high uptime and high performance is crucial for applications such as timing, geodesy and navigation. Building on the expertise obtained within the funded research project *opticlock*, we present here a commercial OFS prototype, TOPTICLOCK, based on the $^2S_{1/2}(F=0) \to {}^2D_{3/2}(F=2)$ electric quadrupole transition (E2) at 435.5 nm of a single $^{171}Yb^+$ ion and contained in two 19" racks. The OFS has been transported to the German metrology institute PTB in June 2025 for a full metrological evaluation within the EU project Qu-Test. In comparison with the more stable optical frequency standard PTB-Yb1E3, using a difference frequency comb (TOPTICA DFC) a frequency instability of $5 \times 10^{-15}/\sqrt{\tau}$ with a total systematic uncertainty below 2×10^{-17} of the OFS was demonstrated. Even for averaging times beyond 10^5 s, the system shows white frequency noise behavior.

Q 50.4 Thu 11:45 P 11

Anomalous tilts and shifts of diffraction orders in Bragg beam-splitters — •Adam Abdalla, Abhay Mishra, Oleksandr Marchukov, and Reinhold Walser — TU Darmstadt, Institute of Applied Physics, Darmstadt, Germany

Interferometric measurements can be used for quantum metrology and inertial sensing or fundamental physics in space [1]. Atomic beam-splitters are integral devices for in three-dimensional matter-wave interferometers. In typical interferometric experiments with Bose-Einstein condensates, one has a superposition of several wavelets (diffraction orders) that extend in the longitudinal x-direction over many optical wavelength λ_L and are much smaller than the Gaussian laser waist $w_0 \gg \sigma_{y,z}$ in the transversal direction [2].

In this contribution, we analyze the Bragg beam splitting of a decentered BEC in real three-dimensional Gaussian laser beams. We find that a Bragg pulse leads to a spatial displacement (shift) of the diffraction wave packets as well as a correction (tilt) to the Bragg momentum $2k_L$ [3]. This is analogous to the Goos-Hänchen effect in optics [4]. The results are supported by (3+1)D simulations of the Gross-Pitaevskii equation. This results will be relevant for any matter-wave interferometers experiments, for example the QUANTUS Collaboration (DLR, grant number 50WM2450E).

[1] D. Becker, et al., Nature **562**, 391 (2018)
[2] A. Neumann, et al., Phys. Rev. A **103**, 043306 (2021)
[3] A. D. Ludlow, Yun Je, et al., Rev. Mod. Phys. **87**, 637 (2015)
[4] F. Goos and H. Hänchen, Annalen der Physik **436**, 333 (1947)

Q 50.5 Thu 12:00 P 11

Unified Theory of Large Momentum Transfer in Optical Lattices — •Patrik Mönkeberg[1], Ashkan Alibabaei[2], Naceur Gaaloul[2], and Klemens Hammerer[1,3,4] — [1]Institute for Theoretical Physics, Leibniz University of Hannover, Germany — [2]Institute of Quantum Optics, Leibniz University of Hannover, Germany — [3]Institute for Theoretical Physics, University of Innsbruck, Austria — [4]Institute for Quantum Optics and Quantum Information of the Austrian Academy of Sciences, Innsbruck, Austria

Large-momentum-transfer techniques are essential tools to enhance the sensitivity of atom interferometers. So far, elastic scattering processes like Bloch oscillations and sequential Bragg diffractions have proven to be effective means of implementing large momentum transfer. To fully exploit the potential of these methods, an accurate theoretical description is crucial. In this work, we utilize a Floquet-theoretical approach to describe both Bloch oscillations and sequential Bragg diffractions as two special cases of a more general framework. We compare different regimes by analyzing losses and phases and offer criteria to reach the fundamental efficiency and accuracy limits. We verify the accuracy of our model through comparisons with exact numerical solutions of the Schrödinger equation and current state-of-the-art experiments [Rodzinka et al., Nat Commun 15, 10281 (2024)].

Q 50.6 Thu 12:15 P 11

Composite light-pulse atom interferometry with Bragg and Raman double diffraction — •Simon Kanthak[1], Ekim T. Hanimeli[2], Matthias Gersemann[3], Mikhail Cheredinov[3], Markus Krutzik[1], Sven Herrmann[2], Sven Abend[3], Ernst M. Rasel[3], and the QUANTUS team[1,2,3,4] — [1]Institut für Physik, HU Berlin — [2]ZARM, Universität Bremen — [3]Institut für Quantenoptik, LU Hannover — [4]Technische Universität Darmstadt

Double diffraction in light-pulse atom interferometry gives rise to symmetric interferometer geometries via oppositely directed momentum transfers. This technique intrinsically doubles the phase sensitivity of the interferometer and suppresses systematic uncertainties, however suffers from spurious atoms in parasitic interferometer paths. While double-diffraction schemes have been implemented using either Bragg or Raman transitions, one has to decide between an enhanced noise-suppression and the straight-forward application of blow-away pulses depending on the absence or presence of internal state changes.

This talk presents a composite light-pulse approach, which relies on a sequence of Bragg and Raman pulses rather than individual ones to exploit manipulations of both the internal and external degrees of atoms. Specifically, we demonstrate the application of Raman state-flips in double Bragg interferometry to recover the interferometric contrast alongside a reduction of the intrinsic phase noise.

The project is supported by the German Space Agency DLR with funds provided by the Federal Ministry for Economic Affairs and Climate Action (BMWK) under grant number DLR 50 WM 2450B.

Q 50.7 Thu 12:30 P 11

Operation of a ring-laser-gyroscope using beam ellipticity — •Marlon Demmerle, Thomas Gereons, Jannik Zenner, and Simon Stellmer — Universität Bonn, Germany

This work introduces a ring-laser-gyroscope exploiting the Sagnac effect to achieve precise rotation sensing, focusing on long-term frequency stability. It uses an ellipticity based locking scheme that leverages higher-order spatial modes without relying on conventional modulation techniques and is directly applicable to all non-linear resonator geometries. By analyzing subtle, mode-dependent changes in the beam shape, the setup attains robust cavity locking while effectively suppressing technical noise. This enables a compact, low-complexity platform for precision rotation measurements and advanced optical metrology.

Q 50.8 Thu 12:45 P 11

Quantum state-selective matter wave diffraction of cold molecules — •Shilpa Yadav, Sejun An, Kilian Hügel, JuHyeon Lee, Gerard Meijer, and Sandra Eibenberger-Arias — Fritz-Haber-Institut der Max-Planck-Gesellschaft, Faradayweg 4-6, 14195

Berlin, Germany.

We propose a novel scheme to spatially separate quantum states of molecules in the gas-phase. In our experiment, we will demonstrate quantum state-selective matter-wave diffraction at an optical grating. In combination with enantiomer-specific quantum state control [1, 2], this will even allow for the spatial separation of chiral molecules in the gas-phase. In my presentation, I will give details on the underlying motivation and physical principles [3,4], as well as information on the current status of the experiment.

1. S. Eibenberger, J. Doyle, and D. Patterson: Enantiomer-Specific State Transfer of Chiral Molecules. Physical Review Letters118, 123002 (2017)

2. J. H. Lee, E. Abdiha, B. G. Sartakov, G. Meijer, and S. Eibenberger-Arias: Near-complete chiral selection in rotational quantum states. Nature Communications 15, 7441 (2024)

3. A. D. Cronin, J. Schmiedmayer, and D. E. Pritchard: Optics and interferometry with atoms and molecules. Reviews of Modern Physics 81, 1051-1129 (2009)

4. K. Hornberger, S. Gerlich, P. Haslinger, S. Nimmrichter, and M. Arndt. Colloquium: Quantum interference of clusters and molecules. Reviews of modern Physics 84, 157-173 (2012)

Q 51: Ultra-cold Atoms, Ions and BEC III (joint session A/Q)

Time: Thursday 11:00–13:00 Location: N 1

Invited Talk Q 51.1 Thu 11:00 N 1

Quantum-enabled active matter at the atomic scale — •Sabrina Burgardt[1], Julian Fess[1], Silvia Hiebel[1], Alexander Guthmann[1], Aritra K. Mukhopadhyay[2], Sangyun Lee[3], Michael te Vrugt[3], Benno Liebchen[2], Hartmut Löwen[4], Raphael Wittkowski[5,6], and Artur Widera[1] — [1]Department of Physics and State Research Center OPTIMAS, RPTU University Kaiserslautern-Landau, Erwin-Schrödinger-Str. 46, 67663 Kaiserslautern, Germany — [2]Institute for Condensed Matter Physics, Technical University of Darmstadt, Hochschulstraße 8, 64285 Darmstadt, Germany — [3]Institute of Physics, Johannes-Gutenberg University Mainz, Staudingerweg 9, 55128 Mainz, Germany — [4]Institute of Theoretical Physics II: Soft Matter, Heinrich-Heine University Düsseldorf, Universitätsstraße 1, 40225 Düsseldorf, Germany — [5]Department of Physics, RWTH Aachen University, Forckenbeckstr. 50, 52074 Aachen, Germany — [6]DWI – Leibniz Institute for Interactive Materials, Forckenbeckstr. 50, 52074 Aachen, Germany

Active particles, which are able to extract energy from their local environment and convert it into motion, have been widely studied in robotics, biology, and soft matter science. So far, it is unclear whether activity can be realized on the much smaller scale of individual quantum systems. Here, we experimentally demonstrate that optically trapped ^{133}Cs atoms are able to extract energy via nonreciprocal quantum-mechanical spin-exchange interactions from a thermal cloud of ^{87}Rb atoms and convert this energy into active motion. It is found that the quantum-enabled activity has significant effects on the in-trap dynamics. We quantitatively reproduce the experimental findings with numerical Monte-Carlo collision simulations and with an active Langevin model for the motion of the ^{133}Cs atoms. Our results open the door to combining effects of quantum mechanics and activity, allowing to design novel exotic far-from-equilibrium systems.

Q 51.2 Thu 11:30 N 1

In-situ observation of density-wave ordering in strongly interacting Fermi gases — •Zeyang Xue, Gaia S. Bolognini, Tabea Bühler, Aurélien Fabre, Kyuhwan Lee, Timo Zwettler, Giulia D. Pace, Victor Helson, and Jean-Philippe Brantut — Institute of Physics and Center for Quantum Science and Engineering, École Polytechnique Fédérale de Lausanne, CH-1015 Lausanne, Switzerland

We study quantum many-body phenomena of strongly correlated fermions. Our setup includes atoms cooled to the degenerate regime and a high-finesse optical cavity. The atoms inside the cavity combine the short-range contact interaction between atoms with the cavity-mediated long-range interaction induced by atoms exchanging photons of the cavity mode. When the strength of the long-range interaction exceeds a critical threshold, the system undergoes a phase transition into a density-wave ordered state. The talk focuses on the first in-situ observation of density-wave ordering. The local density-wave information is extracted by a high-resolution microscope with a numerical aperture of 0.39. We obtain direct information about the phase transition order parameter by quantifying the density-wave modulation contrast. We further investigate the correlation between atomic and photonic signatures of the density-wave ordering phase transition by recording the amplitude and phase of the photonic signal through heterodyne detection. We anticipate further experimental implementations enabled by the high-resolution microscope. For instance, a digital micromirror device (DMD) to apply arbitrary trapping potentials to atoms.

Q 51.3 Thu 11:45 N 1

Time resolved formation dynamics of a heavy Fermi polaron — •Tobias Krom[1], Michael Rautenberg[1], Eugen Dizer[2], Richard Schmidt[2], Olivier Bleu[2], Tilman Enss[2], Lauriane Chomaz[1], and Matthias Weidemüller[1] — [1]Physikalisches Institut, University of Heidelberg — [2]Institute for Theoretical Physics, University of Heidelberg

We study the decoherence of ^{133}Cs impurities within a Fermi sea (3D) of ^{6}Li. As we show, this interacting system of impurities and a degenerate Fermi sea can be well described by the quasiparticle picture introduced by Landau's Fermi liquid theory [1]. The behavior of these emerging quasiparticles scales with the Fermi sea characteristics which allows for complementary studies on different systems. While in metals the Fermi Energy is a few electron volts and its corresponding shortest reaction time τ_F is on the order of 100 attoseconds, ultracold atoms experiments provide much more accessible timescales in the microsecond regime [2].

The chosen combination of atomic species provides the highest mass ratio of 22.2 which can be realized with alkali atoms. Due to this, current quasiparticle theory models cannot fully predict the dynamics, making this experiment a perfect testbed for state-of-the-art polaron theories [3,4].

[1] G. Baym and C. Pethick, Landau Fermi Liquid Theory, 1991
[2] M. Cetina et al 2015 Phys. Rev. Lett. 115, 135302
[3] R. Schmidt et al 2018 Rep. Prog. Phys. 81 024401
[4] Chen et al 2025 Phys. Rev. Lett. 135, 193401

Q 51.4 Thu 12:00 N 1

Spectroscopic structure of the heavy Fermi polaron — •Michael Rautenberg[1], Tobias Krom[1], Eugen Dizer[2], Olivier Bleu[2], Richard Schmidt[2], Tilman Enss[2], Lauriane Chomaz[1], and Matthias Weidemüller[1] — [1]Physikalisches Institut, Heidelberg University — [2]Institut für Theoretische Physik, Heidelberg University

I am going to present our latest spectroscopic measurements on the structure of the heavy Fermi polaron. In our experiment, this system is realized by a few heavy Caesium (^{133}Cs) impurities immersed in a deeply degenerate Fermi gas of much lighter Lithium (^{6}Li) atoms.

While Fermi polarons - quasiparticles formed by impurities dressed by the excitations of a surrounding Fermi sea - are interesting in their own right, the large mass ratio in the Li-Cs system additionally enables addressing questions about the fate of quasiparticles close to the infinitely heavy impurity limit. At this point, Landau's quasiparticle picture [1] breaks down and the system is best described by a new state that is fully orthogonal to the Fermi sea without the impurity - a phenomenon dubbed “Anderson orthogonality catastrophe” [2].

Using tuneable impurity-bath interactions close to a magnetic Li-Cs Feshbach resonance, we can investigate both ground and excited states of the polaron using spectroscopy between two Cs hyperfine states. A careful comparison to different theoretical models sheds light onto the effects of finite temperature and finite mass of the heavy Fermi polaron.

[1] L. D. Landau, Phys. Z. Sowjetunion, 3:644 (1933)
[2] P. W. Anderson, Phys. Rev. Lett. 18, 1049-1051 (1967)

Q 51.5 Thu 12:15 N 1

Determination of the dissipative response of a circularly driven atomic erbium quantum Hall system — •Franz Richard Huybrechts[1], Arif Warsi Laskar[2], and Martin Weitz[1] — [1]University of Bonn, Germany — [2]IIT Guwahati, India

Cold atomic gases are an attractive system for studying topological states and phases. We examine the dissipative response of a synthetic erbium quantum Hall system to two different circular shaking modes. The dissipative response of a quantum Hall system to such a drive is linked to the transport properties, and associated with topological states. In our experiment, the quantum Hall geometry is realised in the two-dimensional state space consisting of one spatial dimension and one synthetic dimension. The latter is encoded in the Zeeman quantum number of erbium atoms in the electronic ground state. Our measurements provide evidence for a difference in the excitation rates between left- and right-handed driving. We will report on the current status of this experiment.

Q 51.6 Thu 12:30 N 1

Exploring dynamic properties of finite-temperature Bose-Einstein condensed bubbles in microgravity — •Brendan Rhyno[1], Timothé Estrampes[1,2], Charles Garcion[1], Zain Mehdi[3], Abel Beregi[4], Jean-Baptiste Gerent[4], Nathan Lundblad[4], Kuei Sun[5], Smitha Vishveshwara[6], and Naceur Gaaloul[1] — [1]Leibniz Universität Hannover — [2]Université Paris-Saclay — [3]Australian National University — [4]Bates College — [5]Washington State University — [6]University of Illinois at Urbana-Champaign

Since the first observation of ultracold bosonic bubbles with the Cold Atom Lab (CAL) aboard the International Space Station, interest in the structure and properties of Bose-Einstein condensate (BEC) bubbles has grown steadily. Motivated by ongoing CAL operations and upcoming microgravity experiments using the Einstein-Elevator at the Leibniz University of Hannover, we discuss our efforts to model the dynamic properties of quantum bubbles. Starting from an initial thermal state, we develop a formalism to compute n-point correlation functions while varying the shell radius and thickness, utilizing an isotropic 'bubble trap' potential. In the ultra-dilute limit, we study nonequilibrium expansions and contractions of the system in the vicinity of the BEC phase transition. In the ultra-thin spherical-shell limit, we develop Bogoliubov techniques for computing nonequilibrium correlators. We conclude by highlighting the relevance of our results to ongoing experimental efforts.

Q 51.7 Thu 12:45 N 1

Towards a dual-species dipolar quantum gas microscope — •Gerard Solà Berga[1], Clemens Ulm[1,2], Eva Casotti[1,2], Andrea Litvinov[1], Manfred J. Mark[1,2], and Francesca Ferlaino[1,2] — [1]Institute for Quantum Optics and Quantum Information Austrian Academy of Sciences, Innsbruck, Austria — [2]Institute for Experimental Physics, University of Innsbruck, Innsbruck, Austria

Ultracold atoms in optical lattices have been established as a powerful toolbox for quantum simulation, enabling the study of many-body physics and strongly correlated condensed matter. In the last decade, single-site imaging and addressing of these lattice-confined atoms has been achieved by the experimental realization of quantum gas microscopes. Until 2023, quantum gas microscopes utilized atomic species with a negligible magnetic moment, which interact exclusively via short-range contact interaction. The addition of long-range interactions in a lattice leads to new exotic phases of matter, such as the Haldane insulator, an interaction-induced topological phase.

Here, we report on the progress towards a quantum gas microscope utilizing the highly dipolar species erbium and dysprosium, which will allow the study of both single- and dual-species physics on the single-atom level. With this new setup, we aim to probe extended Bose- and Fermi-Hubbard models, entering a new quantum simulation framework, beyond the capabilities of conventional short-range interaction setups.

Q 52: Ultra-cold Plasmas and Rydberg Systems II (joint session A/Q)

Time: Thursday 11:00–13:00 Location: N 2

Invited Talk Q 52.1 Thu 11:00 N 2

Long-lived giant circular Rydberg atoms at room temperature — •Fabian Thielemann, Einius Pultinevicius, Aaron Götzelmann, Christian Hölzl, and Florian Meinert — 5 . Physikalisches Institut and Center for Integrated Quantum Science and Technology, Universität Stuttgart, Germany

Atoms in Rydberg states feature long-lived coherent electronic excitations and strong dipolar interactions, making them an attractive platform for quantum simulation and computation. Spinning them up to their maximum allowed angular momentum, to so called circular Rydberg states (CRS), can significantly enhance these desirable properties, e.g. boosting their lifetime from micro- to millisecond timescales. In our experiment we prepare ^{88}Sr atoms in CRS and optically trap them within a room-temperature capacitor structure made from indium-tin-oxide-coated glass. The capacitor inhibits blackbody radiation with wavelengths longer than twice its plate distance, thus significantly suppressing transitions between neighboring CRS with large principal quantum number n. Here, we coherently link CRS with n ranging from 79 up to 101 and demonstrate a capacitor-enhanced lifetime of 10ms [1]. We further show that, owing to their divalent structure, the ^{88}Sr in high angular momentum Rydberg states can be trapped in regular optical tweezers with trapping times exceeding 100ms.

[1] Pultinevicius et al., arXiv:2510.27471 (2025)

Invited Talk Q 52.2 Thu 11:30 N 2

Dynamical decoupling in a dipolar Rydberg gas — •Meny Menashes, Eduard Braun, Matthias Lotze, Maharshi Pran Bora, Gerhard Zürn, and Matthias Weidemüller — Physikalisches Institut, Heidelberg, Germany

We present our ongoing effort to measure out-of-time-order correlators (OTOCs) in a disordered, dipolar Rydberg gas. Building on our recent time-reversal experiments in a dipolar quantum many-body spin system and advances in microwave Hamiltonian engineering, we aim to realize a novel dynamical decoupling protocol based solely on microwave control. This approach enables precise time reversal and suppression of higher-order interactions, providing a clean platform to study information scrambling and quantum dynamics. Via state-selective ionization field tomography reconstruction of the global magnetization is measured, granting access to both global and local observables. The experiment represents a step toward controlled investigations of thermalization, localization, and dynamical quantum phase transitions in isolated long-range interacting spin systems

Q 52.3 Thu 12:00 N 2

Stabilizing a Dissipative Non-Equilibrium Phase Transition — •Patrick Mischke, Herwig Ott, and Thomas Niederprüm — Rheinland-Pfälzische Technische Universität Kaiserslautern-Landau

We experimentally investigate the facilitation dynamics in an ultracold Rydberg system. In the facilitation (≡ anti-blockade) regime, a non-equilibrium phase transition emerges from the interplay between driving and excitation decay.

In an off-resonantly driven cloud of atoms, the strong dipole-dipole interactions between two Rydberg states compensates the laser detuning for a specific interatomic distance, allowing resonant excitations to occur. At sufficiently high atomic densities, this facilitation process leads to the spreading of excitations, forming an active phase, whereas at low densities excitations decay faster than they can propagate, resulting in an absorbing phase. Rydberg excitations that decay to ions are lost from the system and observed at our detector. In order to stabilize the system, this loss must be balanced by a gain process. We implement such gain by optically pumping atoms from a different hyperfine state, allowing us to tune the steady-state density. This stabilization enables measurements of the system dynamics, including correlation functions, over time scales orders of magnitude longer than previously accessible, allowing a systematic characterization of the associated dissipative non-equilibrium phase transition.

Q 52.4 Thu 12:15 N 2

Cryogenic Strontium Quantum Processor — •Xintong Su, Roberto Franco, Valerio Amico, Jonas Drotleff, and Christian Gross — Physikalisches Institut, Eberhard Karls Universität Tübingen, Germany

With the increasing perfection in the control of quantum mechanical many-body systems, first steps for the realization of simple quantum computers have been made. Various physical systems can serve as a basis for such quantum computers. Neutral Rydberg atoms in optical tweezers are among the most promising technologies in the race to build a quantum computer. This platform unites fundamentally indistinguishable qubits and precise control via light fields with scalability in the size of the qubit register. In our project, we work with fermionic 87Sr. The qubit states are defined on two hyperfine sublevels of the ground state. Our goal is to combine the optical tweezer technology with a carefully designed cryogenic setup at 4K. This will result in exceptionally long coherence and lifetime of the atoms in the optical tweezer array and forms the basis for scalability to large atom numbers. Furthermore, the intensity of black-body radiation is strongly reduced in cryogenic environments. Therefore, detrimental coupling between neighbouring Rydberg states, a potential source for collective decoherence in a quantum processor, is suppressed. Finally, the cryogenic environment enables the usage of superconducting coils, which offers outstanding passive stability of the magnetic field and thereby increases the qubit coherence.

Q 52.5 Thu 12:30 N 2

Entanglement of mechanical oscillators mediated by a Rydberg tweezer chain — •Chris Nill[1,2], Cedric Wind[2], Julia Gamper[2], Samuel Germer[2], Valerie Mauth[2], Wolfgang Alt[2], Igor Lesanovsky[1,3], and Sebastian Hofferberth[2] — [1]Institut für Theoretische Physik, University of Tübingen, Auf der Morgenstelle 14, 72076 Tübingen, Germany — [2]Institute for Applied Physics, University of Bonn, Wegelerstraße 8, 53115 Bonn, Germany — [3]School of Physics and Astronomy and Centre for the Mathematics and Theoretical Physics of Quantum Non-Equilibrium Systems, The University of Nottingham, Nottingham, NG7 2RD, United Kingdom

Mechanical systems provide a unique test bed for studying quantum phenomena at macroscopic length scales. However, realizing quantum states that feature quantum correlations among macroscopic mechanical objects remains an experimental challenge. Here, we propose a quantum system in which two micro-electromechanical oscillators interact through a chain of Rydberg atoms confined in optical tweezers [1]. We demonstrate that the coherent dynamics of the system generate entanglement between the oscillators. Furthermore, we utilize the tunability of the radiative decay of the Rydberg atoms for dissipative entanglement generation. Our results highlight the potential to exploit the flexibility and tunability of Rydberg atom chains to generate nonclassical correlations between distant mechanical oscillators.

[1] C. Wind, C. Nill et al., arXiv:2510.08371 (2026).

Q 52.6 Thu 12:45 N 2

Probing localization in a bond-disordered power-law interacting system using time-reversal based protocols — •Eduard Jürgen Braun, Matthias Lotze, Adrian Braemer, Gerhard Zürn, and Matthias Weidemüller — Physikalisches Institut, Universität Heidelberg, Im Neuenheimer Feld 226, 69120 Heidelberg

Quantum thermalization raises intriguing questions about the fate of isolated many-body systems. In conventional one-dimensional systems at finite system size, many-body localization (MBL) appears to defy thermalization, often understood through the emergent integrability encoded in local integrals of motion (LIOMs). However, in systems with long-ranged power-law interactions, the standard LIOM picture is not expected to hold, and recent studies in a bond-disordered model have revealed level statistics markedly different from standard MBL systems. Here, we investigate whether time-reversal-based methods, such as Loschmidt echoes, can uncover distinctive signatures of localization in these bond-disordered power-law interacting systems. Our results suggest that localization in such systems is qualitatively different from conventional MBL, providing new insights into the interplay of disorder and long-ranged interactions.

Q 53: Precision Spectroscopy of Atoms and Ions IV (joint session A/Q)

Time: Thursday 11:00–13:00 Location: N 3

Invited Talk Q 53.1 Thu 11:00 N 3

An optical clock with entangled trapped $^{40}Ca^{+}$ ions. — •Kai Dietze[1,2], Lennart Pelzer[1,2], Bennet Benny[1,2], Fabian Dawel[1,2], Mirza A. Ali[1,2], Derwell Drapier[1], and Piet O. Schmidt[1,2] — [1]QUEST Institute for Experimental Quantum Metrology, Physikalisch-Technische Bundesanstalt, 38116 Braunschweig, Germany — [2]Leibniz Universität Hannover, 30157 Hannover, Germany

Optical atomic clocks based on trapped ions reach fractional systematic uncertainties in the low 10^{-18} range. The statistical uncertainty, however, is typically limited by the quantum projection noise due to the small number of ions, requiring long averaging times to reach a comparable level in uncertainty. Entanglement-assisted interrogation schemes can lower this limit by providing a gain in signal-to-noise ratio. We discuss entanglement-based measurement schemes in the presence of spontaneous emission and magnetic-field fluctuations [2] and present our experimental realization of an optical clock employing two entangled $^{40}Ca^{+}$ ions prepared in a decoherence-free subspace. We experimentally compare a classical correlated protocol with an entanglement enhanced protocol based on a magnetically insensitive multi-ion state, demonstrating lifetime-limited coherence times and their applicability within an optical clock comparison [2].

[1] T. Kielinski et al., Sci. Adv. 10, eadr1439 (2024)
[2] K. Dietze et al., arXiv:2506.11810 (2025)

Q 53.2 Thu 11:30 N 3

Precision Angular Profiling of a Thermal Hydrogen Dissociation Source via Recombination Calorimetry — •Maximilian Balthasar Hüneborn, Sebastian Böser, and Martin Fertl for the Project 8-Collaboration — Johannes Gutenberg-Universität Mainz, Mainz, Germany

Project 8 aims for a 40-meV neutrino mass sensitivity using cyclotron radiation emission spectroscopy (CRES) with atomic tritium to avoid molecular energy uncertainties. At JGU Mainz, the test setup characterizes beam dynamics using a thermal hydrogen dissociation source. Molecular hydrogen flows at up to 20 SCCM through a 1 mm inner diameter tungsten capillary heated to approximately 2200 K, with differential pumping suppressing recombination backgrounds. Precise angular beam profiling is essential to study the beam formation process. We measure the beam profile via a calorimetric wire detector that quantifies recombination heat on a movable tungsten wire, enabling minimally disruptive measurements of beams. A newly built tilt mechanism overcomes the limited angular coverage (-15° to +30°) of the standard translation stage, allowing comprehensive characterization of the beam's full divergence profile. This enables direct comparison between calorimetric and mass spectrometry data, confirming theoretical models of capillary beam output and validating the source geometry's role in atomic beam formation for future tritium operation.

Q 53.3 Thu 11:45 N 3

Spin noise spectroscopy of hot rubidium vapor under two-photon excitation — •Oskar Sund and Ilja Gerhardt — light and matter group, Institute for Solid State Physics, Leibniz University Hannover, Appelstrasse 2,D-30167 Hannover, Germany

Doppler free realized S-P-D transitions in hot rubidium vapor have emerged as a promising contender as stable, compact and low-cost frequency references, potentially superseding the chip-scale atomic clocks of today. Unlike the conventional approach of the two-photon excitation in rubidium at 778.1 nm, a two-color approach would require significantly lower optical powers and vapor densities while achieving comparable frequency stability [1]. In this work, we present two-color, two-beam spin noise spectroscopy: one laser (780 nm) probes ground-state spin fluctuations, while a second laser (776 nm) completes the 5S-5D ladder-type two-photon transition. By measuring the spin noise on both beams, as well as their noise correlation, we investigate how the two-photon excitation perturbs ground-state spin dynamics and whether additional spin noise features or dynamic back-action from excited states can be observed. Such measurements provide new insights into nonlinear spin-light interactions, potentially relevant for precision metrology, quantum sensing and future frequency standards.

[1] Ahern, E. J., Scholten, S. K., Locke, C. et al. Tailoring the stability of a two-color, two-photon rubidium frequency standard. Phys. Rev. Applied 23, 044025 (2025)

Q 53.4 Thu 12:00 N 3

High-resolution laser spectroscopy on iron — •Katrin

Weidner[1], Thorben Niemeyer[1], Jakob Weiss[1], Sebastian Berndt[1], Pia Breinbauer[1], Christoph E. Düllmann[1,2,3], Raphael Hasse[1], Dennis Renisch[1,2], Jörg Runke[1,2], Matou Stemmler[1], Dominik Studer[2], Sebastian Raeder[2], and Klaus Wendt[1] — [1]Johannes-Gutenber-Universität Mainz — [2]Helmholtz-Institut Mainz — [3]GSI Helmholtzzentrum für Schwerionenforschung Darmstadt

High-resolution laser spectroscopy on free atoms provides access to fundamental properties of the atomic and nuclear structure of matter. Iron is among the most abundant metals on Earth and also plays a major role in astronomical observations.

We present high resolution measurements on iron isotopes, addressing the first measurement on the hyperfine structure of the radioisotope ^{55}Fe . An efficient three-step ionization scheme is used for excitations with high-power tunable Titan:Sapphire lasers, including second harmonic generation. To investigate the hyperfine structure we explore injection locking with a commercial Optical Parametric Oscillator (OPO).

Q 53.5 Thu 12:15 N 3

DRALS: A new tool to investigate the hyperfine structure in highly charged ions — •Dimitrios Zisis for the LIBELLE-Collaboration — Institut für Kernphysik, Technische Universität Darmstadt, Germany — Helmholtz Forschungsakademie Hessen für FAIR, Campus Darmstadt, Germany

We report on the first laser excitation of the ground-state hyperfine transition in lithium-like ^{208}Bi^{80+}. The experiment was performed at the ESR, in May 2025. Detection of the transition was enabled through a new measurement scheme that combines laser excitation with dielectronic recombination (DR). In this approach, the electron cooler is set to a voltage that leads to the DR process predominantly from the upper hyperfine state. Resonant laser driving of the transition to the upper state thus leads to an enhancement of the DR recombination rate detected with particle detectors behind the electron cooler.

This technique has been successfully demonstrated for the first time using the radioactive isotope ^{208}Bi in the lithium-like charge state, a species that is inherently difficult to produce, decelerate, and store at the required energies in the ESR. These results establish the feasibility of the method and pave the way for precision measurements during the next beam time, which has already been approved by the GPAC (Proposal G-24-00290). This research was funded by BMFTR, Contract numbers 05P24RD5, 05P21RGFA1 and 5P24RG2.

Q 53.6 Thu 12:30 N 3

The long range validity of the Wigner law - experimental test on negative oxygen — •Thorben Niemeyer[1], Oliver Forstner[2,3,4], Vadim Gadelshin[1], Raphael Hasse[1], Lothar Schmidt[5], Markus Schöffler[5], Matou Stemmler[1], Dominik Studer[1], and Klaus Wendt[1] — [1]Johannes Gutenberg-Universität Mainz — [2]Friedrich-Schiller-Universität Jena — [3]GSI Darmstadt — [4]Helmholtz Institut Jena — [5]Johann Wolfgang-Goethe Universität Frankfurt am Main

Negative atoms are quantum systems in which an additional electron is bound to the neutral core because of electron correlation effects. Correspondingly, its binding energy is one of the most fundamental properties and its knowledge is important for understanding those fragile quantum systems. The detachment of the additional electron by a photon via laser-ion interaction is a well-established measurement technique. It was recently performed on negative oxygen ions at the Frankfurt Low-energy storage ring FLSR. While the cross section curves near the energy threshold obtained in those kinds of measurements are typically well described by the Wigner law, the description further off from thresholds demands a more elaborate theory.

The measured detachment curve on negative oxygen comprises six photodetachment channels distributed over about 50 meV. We discuss the description of the combined threshold curve, in the Wigner appraoch in comparison to the more refined zero-core contribution theory.

Q 53.7 Thu 12:45 N 3

Assessment of the differential polarizability of Yb^+ and Sr^+ clock transitions — •Martin Steinel[1], Thomas Lindvall[2], Marianna Safronova[3], Melina Filzinger[1], Jian Jiang[1], Saaswath JK[1], Ekkehard Peik[1], and Nils Huntemann[1] — [1]Physikalisch-Technische Bundesanstalt, Bundesallee 100, 38116 Braunschweig — [2]VTT Technical Research Centre of Finland, National Metrology Institute VTT MIKES, P.O. Box 1000, 02044 VTT, Finland — [3]University of Delaware, Newark, USA

Optical clocks are leading candidates for a redefinition of the second, with estimated fractional uncertainties at the $6{\times}10^{-19}$ level [1]. Room-temperature ^{171}Yb$^+$ clocks operating on the $S_{1/2} \rightarrow F_{7/2}$ electric-octupole (E3) transition currently reach 3×10^{-18} [2], limited by the blackbody-radiation (BBR) shift $\Delta\nu_{\mathrm{BBR}} \propto \Delta\alpha T^4$. The dominant uncertainty arises from the $\sim 2\%$ accuracy of the differential polarizability $\Delta\alpha$, determined from measurements of the light shift induced by an infrared laser with calibrated optical power and in-situ estimate of the beam profile. In contrast, a method balancing the Stark and Doppler shift caused by excess micromotion yields a $\Delta\alpha$ uncertainty of 0.04% for ^{88}Sr$^+$ [3]. We present direct comparisons of both techniques using ^{88}Sr$^+$ and determine the ratio of $\Delta\alpha$ for ^{171}Yb$^+$ and ^{88}Sr$^+$, enabling a potential reduction of the E3 BBR-shift uncertainty to 2×10^{-19}.

[1] M. C. Marshall et al., Phys. Rev. Lett. 135, 033201 (2025) [2] N. Huntemann et al., Phys. Rev. Lett. 116, 063001 (2016) [3] T. Lindvall et al., Phys. Rev. Lett. 135, 043402 (2025)

Q 54: Members' Assembly

This is the annual assembly of the Quantum Optics and Photonics Division (FV Q). All members are invited to attend. Snacks will be provided. Agenda items may be suggested by e-mail to the Speaker, juergen.eschner@physik.uni-saarland.de.

Time: Thursday 13:15–14:15 Location: P 10

60 min. discussion

Q 55: Optomechanics

Time: Thursday 14:30–16:30 Location: P 2

Q 55.1 Thu 14:30 P 2

Phase-adaptive cooling of fringe-trapped nanoparticles in hollow-core fiber — Soumya Chakraborty[1,2], •Gordon K. L. Wong[1], Pardeep Kumar[1], Hyunjun Nam[1,2], Claudiu Genes[3,1], and Nicolas Y. Joly[2,1] — [1]Max Planck Institute for the Science of Light, Staudtstrasse 2, D-91058 Erlangen, Germany — [2]Department of Physics, Friedrich-Alexander-University Erlangen-Nuremberg, Staudtstrasse 7, D-91058 Erlangen, Germany — [3]TU Darmstadt, Institute for Applied Physics, Hochschulstrasse 4A, D-64289 Darmstadt, Germany

Freezing thermally driven center-of-mass (CoM) motion is essential for accessing quantum effects in macroscopic systems. Here, we experimentally demonstrate a novel phase-adaptive feedback cooling of optically levitated silica nanoparticles inside a hollow-core photonic crystal fiber at room temperature. The particle is tweezed in a standing-wave potential formed by two co-linearly polarized counterpropagating fiber-guided modes. Its axial CoM motion is cooled by adjusting the relative optical phase of the modes as a response to the particle's momentum, generating a dissipative force without recoil heating. The method is applicable to neutral particles. Using this approach, the CoM temperature of a 195 nm silica particle is reduced to 58.6 K at 0.5 mbar, while for a 400 nm particle the temperature reaches 11 K at the same pressure. A stochastic analytical model accurately reproduces the experimental results. This approach enables long-range, coherent control of mesoscopic particles in fiber-based platforms for future quantum applications.

Q 55.2 Thu 14:45 P 2

Dissipation dilution in 3D direct laser written mechanical resonators — •Daniel Stachanow[1], Lukas Tenbrake[1], Florian Giefer[1], Wolfgang Alt[1], Sebastian Hofferberth[1], and Hannes Pfeifer[2] — [1]Institute of Applied Physics, University of Bonn, Germany — [2]Department of Microtechnology and Nanoscience, Chalmers University of Technology, Gothenburg, Sweden

Optomechanical platforms with high-quality mechanical and optical resonators have a wide application potential ranging from sensing to long-lived storage of quantum information. Recent developments in polymer-based 3D direct laser written structures allow for new paradigms in manufacturing micromechanical resonators due to their flexible geometries, but so far suffer from strong mechanical dissipation. Here, we present our recent progress in implementing and improving this platform. The mechanical Q-factor of the resonator in vacuum is primarily limited by intrinsic losses within the material. However, these losses can be significantly reduced by introducing strain on the membrane, leading to so-called dissipation dilution. This is done by engineering the geometry of the resonator for optimized aspect ratios and adjusting the fabrication process. To quantify the results, a scannable vacuum-integrated fiber cavity setup for probing mechanical resonators is used. We demonstrate the impact of shrinkage-induced strain on the mechanical Q-factor of polymeric bridge-like resonators. Additionally, we report the status of our current developments using post-fabrication treatment of applying oxygen-plasma to further optimize the surface properties and aspect ratios of the structures.

Q 55.3 Thu 15:00 P 2

Coherent scattering of an optically levitated nanoparticle to an ultrahigh-Q microtoroidal cavity — •Zijie Sheng[1], Seyed Khalil Alavi[1], Haneul Lee[2], Hansuek Lee[2,3], and Sungkun Hong[1] — [1]Institute Institute for Functional Matter and Quantum Technologies and Center for Integrated Quantum Science and Technology (IQST), University of Stuttgart, DE — [2]Department of Physics, Korea Advanced Institute of Science and Technology (KAIST), Republic of Korea — [3]Graduate School of Quantum Science and Technology, KAIST, Republic of Korea

Optically levitated dielectric nanoparticle offers a versatile platform for studying quantum physics beyond microscopic domain. Coupling its mechanical motion to the optical cavity enables the investigation of diverse optomechanical phenomena, which rely strongly on the strength of optomechanical coupling. An effective approach to enhancing the coupling is cavity-enhanced coherent scattering, where the cavity mode is driven by photon coherently scattered from the nanoparticle. Using this scheme, quantum ground state cooling has been achieved with the conventional Fabry-Pérot mirror cavity in weak coupling regime. Here we present the coherent scattering of the nanoparticle trapped by optical tweezer to a silica toroidal optical microcavity, where the significantly reduced mode volume enhances the optomechanical coupling, placing our platform in the ultrastrong coupling regime ($g \gg \omega$). We will report the key findings in this regime, together with the significant anomalous cooling to be explained.

Q 55.4 Thu 15:15 P 2

Amplification of optical forces via interference in levitated optomechanics — •Youssef Ezzo, Seyed Khalil Alavi, Ashik Pulikkathara, and Sungkun Hong — Institute for Functional Matter and Quantum Technologies and Center for Integrated Quantum Science and Technology (IQST), University of Stuttgart, 70569 Stuttgart, Germany

Precise tailoring of optical forces is fundamental to the control of levitated mesoscopic particles. While direct radiation pressure is typically the dominant mechanism, interference effects offer a powerful route to engineer light-matter interactions. In this work, we demonstrate the significant amplification of optical forces exerted by weak light fields through their interference with a strong trapping beam. By co-propagating a weak signal field with the optical tweezer, we exploit the interference term to generate an enhanced force that scales linearly with the signal field amplitude, rather than its intensity. We experimentally characterize this force enhancement using a silica nanoparticle, resolving the mechanical motion driven by weak fields with a sensitivity of 37.2 pW/Hz. We further discuss how this interference-based force scaling can be extended to counter-propagating geometries to maximize interaction strengths, enabling zeptowatt-level force control and efficient 3D all-optical cooling.

Q 55.5 Thu 15:30 P 2

Release and recapture of millikelvin cooled levitated nanoparticles in microgravity conditions — •Govindarajan Prakash[1], Sven Herrmann[1], Ralf B. Bergmann[2], and Christian Vogt[2] — [1]Zentrum für Angewandte Raumfahrttechnologie und Mikrogravitation (ZARM), Universität Bremen, Bremen, Germany — [2]BIAS - Bremer Institut für Angewandte Strahltechnik GmbH, Klagenfurter Str. 5, 28359 Bremen, Germany

Optomechanical levitation of nanoparticles provides a promising platform to perform tests with macroscopic particles on the interface between quantum and classical regimes. Many proposed schemes involve free evolution of such a particle after preparation in a known quantum state. Increasing mass requires increased free evolution times for which even space-based experiments have been proposed. As a first step in this direction, we have performed experiments with a millikelvin cooled levitated silica nanoparticle at the Gravitower Bremen Pro. We use the microgravity conditions of the facility to try and extend the free-fall duration of the nanoparticle to greater than what is possible on ground[1]. So far, we have achieved up to 300 microseconds of free-fall duration with a single beam trap. In this talk, we will present the analysis of the first results, limitations, and possible improvements to our current setup.

[1]. Prakash, G., Herrmann, S., Bergmann, R. B. & Vogt, C. Release and recapture of silica nanoparticles from an optical trap in weightlessness. arXiv:2509.08666 [physics.optics] (2025)

Q 55.6 Thu 15:45 P 2

Probing Quantum Mechanics with Nanorotors — Stephan Troyer[1], •Florian Fechtel[1], Henning Rudolph[2], Benjamin Stickler[3], Uroš Delić[4], and Markus Arndt[1] — [1]University of Vienna, VDS, VCQ, Faculty of Physics, Boltzmanngasse 5, A-1090 Vienna, Austria — [2]University of Duisburg-Essen, Faculty of Physics, Lotharstraße 1, 47057 Duisburg, Germany — [3]Ulm University, Albert-Einstein-Allee 11, 89069 Ulm, Germany — [4]TU Wien, Stadionallee 2, 1020 Vienna, Austria

Levitated nanoparticles are promising candidates for observing quantum effects and even matter-wave interference at unprecedented mass scales. In this regime, the rotational dynamics are particularly intriguing, as the nonlinear motion on a compact, closed configuration space provides a rich platform for phenomena such as interference or quantum tunnelling. To access these effects, quantum control over the rotational motion is essential. For instance, rotational revival necessitates a tightly aligned nanorotor, motivating cooling of at least two librational modes. Coherent scattering cooling provides a versatile method capable of coupling simultaneously to multiple motional degrees of freedom. In our implementation, a cavity supporting two orthogonal optical modes couples each mode to one librational mode. When the frequency splitting between the librational modes is comparable to the cavity linewidth, efficient two-mode cooling becomes experimentally feasible. Aligning a nanorotor with a well-characterized geometry that supports millisecond-scale revival times will open the door to future experiments on rotational interference.

Q 55.7 Thu 16:00 P 2

Tunable light induced dipole-dipole interactions — •Livia Egyed[1], Manual Reisenbauer[1], Henning Rudolph[3], Murad Abuzarli[2], Klaus Hornberger[3], Anton Zasedatelev[5], Benjamin Stickler[4], and Uros Delic[1] — [1]Atominstitut, Technische Universität Wien, A-1020 Vienna, Austria — [2]Vienna Center for Quantum Science and Technology (VCQ), Faculty of Physics, University of Vienna, A-1090 Vienna, Austria — [3]Faculty of Physics, University of Duisburg-Essen, 47048 Duisburg, Germany — [4]Institute for Complex Quantum Systems, Ulm University, D-89069 Ulm, Germany — [5]Department of Applied Physics, Aalto University School of Science, FI-00076 Espoo, Finland

Tweezer arrays can be used to trap, arrange, and control atoms or dielectric nanoparticles, while ensuring strong environmental isolation. Our platform of programmable arrays of levitated nanoparticles with highly tunable optical interactions provide access to a wide range of system parameters, enabling us to adjust the coupling between the particles from fully reciprocal to uni-directional and up until fully anti-reciprocal by modifying their trapping fields. In case of anti-reciprocal coupling, we observe PT-symmetry breaking, and for strong coupling rates the system transitions into a mechanical lasing phase. Furthermore, dynamically modulating the trapping potential of particles with non-degenerate mechanical frequencies allows us to engineer an arbitrary combination of beamsplitter and two-mode squeezing type interactions between them.

Q 55.8 Thu 16:15 P 2

Entanglement of nanoparticles via Coulomb force under optimal control — •Nancy Gupta[1,2], Ayub Khodaee[1,2], Klemens Winkler[1], Kaspar Schmerling[3], Andreas Deutschmann-Olek[3], Nikolai Kiesel[1], Anton Zasedatelev[5], Uroš Delić[4], and Markus Aspelmeyer[1,2] — [1]University of Vienna, Faculty of Physics, Vienna Center for Quantum Science and Technology (VCQ), Boltzmanngasse 5, A-1090 Vienna, Austria — [2]Institute for Quantum Optics and Quantum Information, Austrian Academy of Sciences, A-1090 Vienna, Austria. — [3]Automation and Control Institute (ACIN), TU Wien, 1040 Vienna, Austria — [4]Atominstitut, TU Wien — [5]Department of Applied Physics, Aalto University

Optomechanics with levitated particles offers a powerful route to explore quantum behavior at macroscopic scales, including ground-state cooling. A central goal is to entangle the motion of two levitated nanoparticles to study decoherence, but weak interactions have limited the experimental progress. We address this challenge using electrostatic Coulomb forces between two optically trapped silica particles. By employing active and passive charging, we achieve strong coupling with an interaction strength of 17 percent of the mechanical frequency and realise cooling and readout of the coupled modes. Because steady-state entanglement demands stronger coupling, we introduce an optimal-control protocol that exploits time-dependent interactions in a continuously measured system. This approach relaxes coupling requirements and enables unconditional entanglement while addressing stabilization, feedback, and noise near the ground state.

Q 56: Quantum Optics and Control I

Time: Thursday 14:30–16:30 Location: P 3

Invited Talk Q 56.1 Thu 14:30 P 3

Quantum logic control of transition metal and molecular ions — Till Rehmert[1,2], Maximilian J. Zawierucha[1,2], Kai Dietze[1,2], Piet O. Schmidt[1,2], Sergey G. Porsev[3], Dmytro Filin[3], Charles Cheung[3], Marianna S Safronova[3], and •Fabian Wolf[1] — [1]Physikalisch-Technische Bundesanstalt, Bundesallee 100, 38116 Braunschweig — [2]Institut für Quantenoptik, Leibniz Universität Hannover, Welfengarten 1, 30167 Hannover — [3]Department of Physics and Astronomy, University of Delaware, Delaware 19716, USA

Extending quantum control to increasingly complex systems, such as molecular ions, is essential for advancing quantum technologies and probing fundamental physics.

Quantum logic spectroscopy offers a promising route to controlling molecular ions: a well-controlled atomic ion is co-trapped with a molecular ion and enables manipulation and readout of its quantum state via shared motional modes. As we move toward quantum logic spectroscopy of single molecular MgH^+ ions, we are also exploring the applicability of these techniques to other species. Recently, we demonstrated quantum logic control of a single titanium ion, showing that these methods extend to previously inaccessible atomic systems.

By expanding quantum control to new classes of ions, our work enables new opportunities in precision spectroscopy, quantum technology, and fundamental physics.

Q 56.2 Thu 15:00 P 3

Multi-Path and Multi-Particle Tests of Complex versus Hyper-Complex Quantum Theory — Ece Ipek Saruhan, Joachim von Zanthier, and •Marc-Oliver Pleinert — Quantum Optics and Quantum Information Group, Friedrich-Alexander Universität Erlangen-Nürnberg, Staudtstr. 1, 91058 Erlangen, Germany

The axioms of quantum mechanics provide limited information regarding the structure of the Hilbert space, such as the underlying number system. The latter is generally regarded as complex, but generalizations of complex numbers, so-called hyper-complex numbers, cannot be ruled out in theory. Therefore, specialized experiments to test for hyper-complex quantum mechanics are needed. To date, experimental tests are limited to single-particle interference exploiting a closed phase relation in a three-path interferometer called the Peres test. The latter distinguishes complex quantum mechanics from quaternionic quantum mechanics. Here, we propose a general matrix formalism putting the Peres test on a solid mathematical ground. On this basis, we introduce multi-path and multi-particle interference tests, which provide a direct probe for any dimension of the number system of quantum mechanics.

[Phys. Rev. Lett. 134, 060201 (2025)]

Q 56.3 Thu 15:15 P 3

Towards generalized pump beam engineering for maximal entanglement in Laguerre-Gaussian modes — •Richard Bernecker[1,2], Baghdasar Baghdasaryan[3], and Stephan Fritzsche[1,2] — [1]Institute for Theoretical Physics, Friedrich Schiller University Jena, Fröbelstieg 1, 07743 Jena, Germany — [2]Helmholtz Institute Jena, Fröbelstieg 3, 07743 Jena, Germany — [3]Institute of Applied Physics, Friedrich Schiller University Jena, Albert-Einstein-Str. 6, 07745 Jena, Germany

The spatial entanglement of photons in Laguerre-Gaussian (LG) modes has proven to be a powerful resource for high-dimensional quantum information processing. LG modes are indexed by a radial number p and an azimuthal number ℓ, the latter being associated with orbital angular momentum (OAM). While most studies over the past decades have focused on the OAM, recent advances now enable full-mode characterization, including the radial index p. However, no general strategy exists to generate specific high-dimensional target states in the full LG basis.

In this contribution, we present a generalized approach to spatial pump-beam engineering that enables the generation of maximally entangled states (MESs) from spontaneous parametric down-conversion. MESs constitute the high-dimensional analogue of Bell states and form ideal resources for quantum information tasks. We show that a tailored superposition of LG pump modes, combined with an optimized choice of the detection subspace, allows for the controlled engineering of MESs across both radial and azimuthal mode indices.

Q 56.4 Thu 15:30 P 3

Observation of entanglement between free electrons and photons — •Jan-Wilke Henke[1,2], Hao Jeng[1,2], Murat Sivis[1,2], and Claus Ropers[1,2] — [1]Max Planck Institute for Multidisciplinary Sciences, Göttingen, Germany — [2]University of Göttingen, 4th Physical Institute, Göttingen, Germany

Entanglement is central to most emerging quantum technologies from quantum computation to quantum sensing. Generating entangled quantum states is thus highly relevant for future applications, and has been achieved in various combinations of quantum systems. Here, we demonstrate the quantum entanglement between free electrons and photons [1]. In a quantum eraser-type scheme [2], we use a coherently split electron beam to generate photons of distinct polarisation at a specifically designed nanostructure placed in a transmission electron microscope. Performing electron-photon coincidence measurements in different bases, we reconstruct the joint electron-photon state and show that it violates the Peres-Horodecki entanglement criterion by more than 7 standard deviations. Laying the basis for quantum-enhanced sensing in the electron microscope, the proof of electron-photon entanglement represents a cornerstone of free electron quantum optics. [1] J.-W. Henke et al., arXiv:2504.13047 (2025); [2] J.-W. Henke, H. Jeng & C. Ropers, Phys. Rev. A 111, 012610 (2025)

Q 56.5 Thu 15:45 P 3

Single- and many-body interference in a generalized Mach-Zehnder interferometer — •Farouk Albalacy, Gabriel Dufour, and Andreas Buchleitner — Physikalisches Institut & EUCOR Centre for Quantum Science and Quantum Computing, Albert-Ludwigs-Universität Freiburg

We study the interplay of single- and many-body interference effects by injecting one quantum object per port in a generalized Mach-Zehnder interferometer with three ports. Single-body interference is controlled by the phase shifts between the paths of the interferometer. The effect of bosonic many-body interference is singled out by tuning the individual constituents' mutual distinguishabilities through their internal states. We analyze the output counting statistics for three partially distinguishable bosons, as a function of their internal states and of the interferometer phases.

Q 56.6 Thu 16:00 P 3

Entanglement shortcuts in the geometry of micromaser state preparation — •Matthias Bundy[1], Christoph Dittel[1,2], and Andreas Buchleitner[1,2] — [1]Physikalisches Institut, Albert-Ludwigs-Universität, Hermann-Herder-Straße 3, 79104 Freiburg, Germany — [2]EUCOR Centre for Quantum Science and Quantum Computing, Albert-Ludwigs-Universität Freiburg, Hermann-Herder-Straße 3, 79104 Freiburg, Germany

Any desired state of a single, quantized cavity mode can be prepared by sequentially interacting with a string of two-level atoms. However, the fidelity of the preparation process much depends on the desired target state, the number of atoms, and the degree of their mutual entanglement. Here we investigate the state preparation process from a geometric perspective, by establishing an appropriate metric for the length of state preparation trajectories. We quantify how the entanglement of the atomic string shortens the path from the cavity mode's initial to target state, and discuss how these trajectories differ for classical and non-classical target states.

Q 56.7 Thu 16:15 P 3

Phase-sensitivity enhancement in Mach-Zehnder interferometer via local Gaussian operations — Taj Kumar, Krishna Mohan Mishra, Aviral Kumar Pandey, Vikas Kumar Prajapati, and •Devendra Kumar Mishra — Department of Physics, Institute of Science, Banaras Hindu University, Varanasi-221005, Uttar Pradesh, India

We investigate the role of local Gaussian operations, specifically local displacement operation (LDO) and local squeezing operation (LSO), in enhancing the phase sensitivity of the Mach-Zehnder interferometer (MZI). We considered two scenarios: when these operations are applied in a single arm only and when they are applied in both arms of the MZI. Using coherent and squeezed vacuum states as inputs and homodyne detection, we analyze the phase sensitivity and the quantum Cramér-Rao bound (QCRB) under both ideal and lossy conditions. Our study reveals that both single- and dual-arm LDO schemes offer equivalent improvements in phase sensitivity. However, the single-arm LSO scheme offers improved phase sensitivity that is superior to its dual-arm counterpart as well. In short, the single-arm configuration is found to be more resource-efficient, providing improved phase sensitivity and enhanced robustness against photon losses. These results emphasize the advantages of the Gaussian operations, such as LDO and LSO, as an experimentally feasible approach with a low implementation cost for achieving enhanced phase sensitivity and robustness against photon losses.

Q 57: Open Quantum Systems III

Time: Thursday 14:30–16:30 Location: P 4

Q 57.1 Thu 14:30 P 4

Non-unitarity maximizing unraveling of open quantum dynamics — •Ruben Daraban, Fabrizio Salas-Ramirez, and Johannes Schachenmayer — University of Strasbourg

The dynamics of many-body quantum states in open systems is commonly numerically simulated by unraveling the density matrix into pure-state trajectories. In this work, we introduce a new unraveling strategy that can adaptively minimize the averaged entanglement in the trajectory states. This enables a more efficient classical representation of trajectories using matrix product decompositions. Our new approach is denoted non-unitarity maximizing unraveling (NUMU). It relies on the idea that adaptively maximizing the averaged non-unitarity of a set of Kraus operators leads to a more efficient trajectory entanglement destruction. Compared to other adaptive entanglement lowering algorithms, NUMU is computationally inexpensive. We demonstrate its utility in large-scale simulations with random quantum circuits. NUMU lowers runtimes in practical calculations, and it also provides new insight on the question of classical simulability of quantum dynamics. We show that for the quantum circuits considered here, unraveling methods are much less efficient than full matrix product density operator simulations, hinting to a still large potential for finding more advanced adaptive unraveling schemes.

Q 57.2 Thu 14:45 P 4

Deterministic Quantum Jump (DQJ) Method for Weakly Dissipative Systems — •Marcus Meschede[1] and Ludwig Mathey[1,2] — [1]Center for Optical Quantum Technologies and Institute for Quantum Physics, University of Hamburg, 22761 Hamburg, Germany — [2]The Hamburg Center for Ultrafast Imaging, Luruper Chaussee 149, 22761 Hamburg, Germany

Simulating large open quantum systems is computationally expensive due to the complexity scaling of the density matrix formalism. Instead of time evolving the total density matrix, Quantum jump methods approximate the evolution through a statistical ensemble of quantum jump trajectories. In this work, we propose the Deterministic Quantum Jump (DQJ) method for the weak dissipation limit of the Lindblad master equation. In DQJ, quantum jumps are deterministically placed on a suitable jump time grid. For time evolutions in which the probability of trajectories with few jumps dominate higher order jump trajectories N, we show that the infidelity of the DQJ method with the true evolution can scale with $\propto 1/N^4$ in the number of trajectories. This drastically outperforms the Standard Quantum jump (SQJ) method, scaling with $\propto 1/N$. We demonstrate the improved scaling on the evolution of a system of coupled qubits as well as on the the spectrum of a Kerr-anharmonic oscillator. Generally, our DQJ method is suitable to all systems in which quantities are sensitive to weak coupling to the environment. In particular, it is native to the field of quantum computing, e.g. cQED setups, in which the weak coupling to the environment is crucial in evaluating quantum protocols.

Q 57.3 Thu 15:00 P 4

Stable Quantum Trajectories for Pseudo-Lindblad Equations — •Lorenz Wanckel and André Eckardt — Technical University of Berlin, Institute for Physics and Astronomy

In open quantum systems beyond the ultraweak coupling regime, master equations such as the Redfield equation, which are not of Lindblad but of pseudo-Lindblad form, are often used. This prevents the application of the standard Monte Carlo wave-function unraveling introduced by Dalibard et al. The Pseudo-Lindblad Quantum Trajectory (PLQT) approach, introduced by Becker et al., provides an unraveling of pseudo-Lindblad equations without the need to enlarge the Hilbert space, but it exhibits inherent long-time instabilities due to exponentially growing fluctuations. We present a stabilized PLQT algorithm that suppresses these fluctuations, thereby enabling reliable simulations up to and including the steady state.

Q 57.4 Thu 15:15 P 4

Open quantum system dynamics with semi-group influence matrices — •Valentin Link[1], Hong-Hao Tu[2], and Walter Strunz[3] — [1]Institut für Physik und Astronomie, Technische Universität Berlin, 10623, Berlin, Germany — [2]Faculty of Physics and Arnold Sommerfeld Center for Theoretical Physics, Ludwig-Maximilians-Universität München, 80333 München, Germany — [3]Institut für Theoretische Physik, Technische Universität Dresden, 01062, Dresden, Germany

Approaching the long-time dynamics of non-Markovian open quantum systems presents a challenging task when the bath is strongly coupled. Recent proposals address this problem by representing temporal correlations encoded in the environmental influence matrix in terms of a compressed matrix product operator (MPO). I present a highly efficient algorithm to generate such an MPO form, utilizing infinite tensor-network methods. The resulting uniform MPO representation defines a dynamical semigroup in a reduced auxiliary space, allowing us to directly target long evolution times. I demonstrate the capabilities of this approach for computing dynamical quantities in spin-boson and single-impurity Anderson models.

[1] V. Link, H. H. Tu, W. T. Strunz, Phys. Rev. Lett. 132, 200403 (2024) [2] M. Sonner, V. Link, D. A. Abanin, Phys. Rev. Lett. 135,

170402 (2025)

Q 57.5 Thu 15:30 P 4

A witness of superluminal signalling in quantum theory and its modifications. — •Aritro Mukherjee — University of Duisburg-Essen

Linearity of the master equations in quantum theory and in many of its proposed modifications is often taken to guarantee the absence of superluminal signalling, thereby preserving causality. However, in many scenarios, master equations are not always available in a closed analytic form, limiting the applicability of this argument. To address this, we first introduce a general operational witness for detecting superluminal signalling which does not rely on explicit knowledge of a master equation and is easily assessed when analytical methods are not available. Furthermore, applying this witness reveals a surprising result: even linear master equations can permit superluminal signalling unless a specific locality condition is satsfied by the master equations. Hence we show that linearity of the corresponding master equations is not sufficient towards preserving causality. In contrast, the witness we propose provides a necessary and sufficient criterion for ruling out superluminal signalling in full generality. Ref: arXiv:2410.08844 / Phys. Rev. A 112, 062202 (2025)

Q 57.6 Thu 15:45 P 4

Perturbative and non-perturbative continuous similarity transformations for Lindbladians — •Lea Lenke and Kai Phillip Schmidt — FAU Erlangen-Nürnberg

We study the Lindbladian of the dissipative transverse field Ising chain by continuous similarity transformations (CSTs). The latter are the two flow equation methods pcst^{++} and directly evaluated enhanced perturbative continuous unitary transformations (deepCUTs) which both generate effective block-diagonal operators. The first method, pcst^{++}, is a generalization of the method of perturbative continuous unitary transformations (pCUTs) to non-Hermitian operators like the Lindbladian and multiple quasiparticle types. The second method, deepCUT, uses a perturbative truncation scheme to generate a non-perturbative expansion of the effective operator. We apply the same generator as in the definition of the pcst^{++} to generalize deepCUT to non-Hermitian operators. We apply both methods to the Lindbladian describing the dissipative transverse field Ising chain. In the subsequent treatment of the obtained effective Lindbladian, we take advantage of its block-diagonal structure and perform a linked-cluster expansion obtaining results that are valid in the thermodynamic limit.

Q 57.7 Thu 16:00 P 4

Recursive perturbation approach to time-convolutionless master equations: Explicit construction of generalized Lindblad generators for arbitrary open systems — •Alessandra Colla[1,2,3], Heinz Peter Breuer[3,4], and Giulio Gasbarri[5,6] — [1]Dipartimento di Fisica Aldo Pontremoli, Università degli Studi di Milano, Via Celoria 16, I-20133 Milan, ItalyDipartimento di Fisica *Aldo Pontremoli*, Università degli Studi di Milano, Via Celoria 16, I-20133 Milan, Italy — [2]INFN, Sezione di Milano, Via Celoria 16, I-20133 Milan, Italy — [3]Institute of Physics, University of Freiburg, Hermann-Herder-Straße 3, D-79104 Freiburg, Germany — [4]EUCOR Centre for Quantum Science and Quantum Computing,University of Freiburg, Hermann-Herder-Straße 3, D-79104 Freiburg, Germany — [5]Naturwissenschaftlich-Technische Fakultät, Universität Siegen, Siegen 57068, Germany — [6]Física Teòrica: Informació i Fenòmens Quàntics, Department de Física, Universitat Autònoma de Barcelona, 08193 Bellaterra (Barcelona), Spain

We present a recursive perturbative expansion for the time-convolutionless (TCL) generator of an open quantum system that preserves a generalized Lindblad-like structure at every order, assuming only an initially uncorrelated system*environment state. The generator is cast in a canonical, minimal-dissipation form that uniquely splits coherent (Hamiltonian) and dissipative contributions

Q 57.8 Thu 16:15 P 4

Artificial discovery of lattice models for wave transport — •Jonas Landgraf[1,2], Clara Wanjura[1], Vittorio Peano[1], and Florian Marquardt[1,2] — [1]Max Planck Institute for the Science of Light, Erlangen — [2]University of Erlangen-Nuremberg

Wave transport devices, such as amplifiers, frequency converters, and nonreciprocal devices, are essential for modern communication, signal processing, and sensing applications. Of particular interest are traveling wave setups, which offer excellent gain and bandwidth properties. So far, the conceptual design of those devices has relied on human ingenuity. This makes it difficult and time-consuming to explore the full design space under a variety of constraints and target functionalities. In our work, we present a method that automates this challenge. By optimizing the discrete and continuous parameters of periodic coupled-mode lattices, our approach identifies the simplest lattices that achieve the target transport functionality, and we apply it to discover new schemes for directional amplifiers, isolators, and frequency demultiplexers. Leveraging automated symbolic regression tools, we find closed analytical expressions that facilitate the discovery of generalizable construction rules. Moreover, we utilize important conceptual connections between the device transport properties and non-Hermitian topology. The resulting structures can be implemented on a variety of platforms, including microwave, optical, and optomechanical systems. Our approach opens the door to extensions like the artificial discovery of lattice models with desired properties in higher dimensions or with nonlinear interactions.

Q 58: Quantum Technologies – Color Centers I

Time: Thursday 14:30–16:30 Location: P 5

Q 58.1 Thu 14:30 P 5

Critical Discrete Time Crystal with 3D-dipolar-coupled Nuclear Spins in Diamond — •Christina Ioannou[1], Kai-Niklas Schymik[1], Dan Yudilevich[1], Madhumati Seetharaman[1], Benjamin Pingault[2], Francisco Machado[1], and Tim Taminiau[1] — [1]TU Delft, Delft, Netherlands — [2]Argonne National Laboratory/ University of Chicago, Chicago, USA

We investigate the thermalization dynamics under Floquet driving of a 3D-dipolar-coupled many- body system of 13C nuclear spins in diamond. Microscopic control and readout of 40 individual spins gives in depth insight into many-body dynamics and allows for the observation of novel non-equilibrium phenomena. In the case of a disordered Ising type Hamiltonian, with a local disorder term, long range interactions between spins cause the slow down of thermalization dynamics leading to a long lived critical discrete time crystal (DTC) order. We demonstrate the stability of the DTC order, attributed to critical dynamics and we analyze the underlying thermalization mechanism caused by two spin correlated decays.

Q 58.2 Thu 14:45 P 5

Exact Computation of Lock-In Amplifier Outputs for Arbitrary Frequency Modulations Using Gauss-Chebyshev Quadrature — •Dennis Lönard, Stefan Johansson, Alena Erlenbach, Jonas Gutsche, and Artur Widera — Department of Physics and State Research Center OPTIMAS, University of Kaiserslautern-Landau, 67663 Kaiserslautern, Germany

Lock-in detection is everywhere, from precision sensing to quantum experiments, but the theoretical treatment of frequency-modulated signals often relies on approximations for small modulation deviations. These approximations are especially prominent in fields like nitrogen-vacancy-center magnetometry and laser spectroscopy, where frequency modulation is used to generate an error signal for locking. These approximations break down precisely in the regime where optimal sensitivity is achieved, leading to inaccurate predictions of optimal modulation depth, lineshape, and ultimately experimental performance.

In this talk, we introduce an approximation-free numerical method based on Gauss-Chebyshev quadrature that computes lock-in amplifier outputs for any modulation waveform, modulation function, signal shape, or deviation. This method is exact, fast, and simple to implement, making it applicable to all lock-in-based experiments.

We demonstrate the approach using nitrogen-vacancy-center magnetometry, which reveals the true optimal modulation parameters beyond the commonly assumed small-modulation regime. An open-source Python package accompanies our work, providing a ready-to-use reference implementation.

Q 58.3 Thu 15:00 P 5

Optically Detected Magnetic Resonance on Carbene Molecular Qubits — •Simon Roggors[1,2,3], Nico Striegler[1,2,3], Thomas Unden[1], Oleksiy Khavryuchenko[1,4,5], Alon Salhov[1,6], Jochen Scharpf[1], Martin B. Plenio[3,7], Alex Retzker[6], Fedor Jelezko[2,3], Matthias Pfender[1], Philipp Neumann[1], Tim R. Eichhorn[1], Tobias A. Schaub[1,2,3], and Ilai Schwartz[1] — [1]NVision Imaging Technologies GmbH, Wolfgang-Paul-Str. 2, Ulm 89081, Germany — [2]Institute for Quantum Optics (IQO), Ulm University — [3]Center for Integrated Quantum Science and Technology (IQST), Ulm — [4]Shupyk National Healthcare University of Ukraine — [5]Institute of Organic Chemistry of the National Academy of Sciences of Ukraine — [6]Racah Institute of Physics, The Hebrew University of Jerusalem — [7]Institute of Theoretical Physics, Ulm University

Solid-state quantum systems that integrate optical and spin degrees of freedom are central to emerging quantum technologies, yet their scalability and tunability remains challenging. Molecular qubits embedded in crystalline host matrices offer a promising path forward due to their engineerable optical and spin properties. Here, we introduce ground-state triplet carbenes as fully organic systems that enable spatially precise photoactivation, exhibit large zero-field splitting, and provide clear optical initialization and readout of their spin states with high fluorescence contrast. These systems also maintain remarkably long coherence times at cryogenic temperatures, underscoring their potential as versatile and scalable building blocks for future quantum applications.

Q 58.4 Thu 15:15 P 5

Engineering New Family of Chlorine-Based Emitters in Silicon Carbide for Telecom Band — •Ashin Varghese Mathews[1,2], Andrei Anisimov[1], Kalliopi Mavridou[1], Ulrich Kentsch[1], Manfred Helm[1,2], and Georgy Astakhov[1] — [1]Helmholtz-Zentrum Dresden-Rossendorf, 01328 Dresden, Germany — [2]Technische Universität Dresden, Germany 01069

Efforts to find silicon carbide (SiC) color centers emitting in the telecom O- and C-bands are crucial for quantum communication [1]. While existing defects like Vanadium (V) are promising (O-band emission, coherent control), they require sub-Kelvin temperatures [2]. Theoretical work proposed the chlorine-vacancy (ClV) center as a new, NV-like defect covering 1330nm to 1590nm [3].

This work reports the first experimental observation of ClV centers. Photoluminescence studies show that their emission, spanning the O- and C-bands, is inherently compatible with telecom infrastructure and remains stable up to 30 K. This establishes ClV centers as a highly potential family of SiC defects for scalable quantum technologies [4]. In order to enhance the optical collection efficiency of the ClV, nanopillars are fabricated with different diameters for optimization and the results are presented within this study.

[1] Z. Mu, et al., Adv. Quantum Technol. 4, 2100076 (2021) [2] T. Astner, et al., Quantum Science and Technology 9(3), 035038 (2024) [3] O. Bulancea-Lindvall, et al., Phys. Rev. B 108, 224106 (2023) [4] A. N. Anisimov, et al., arXiv.org, quant-ph, arXiv:2510.25008 [quant-ph] (2025)

Q 58.5 Thu 15:30 P 5

Optical Integration of single NV-centers for Quantum Computing and Sensing — •Lucas Kirchbach[1,2], Andreas Giese[1], Julian Staniewski[2], Manuel Riedmann[2], Robert Bruss[1], Bernd Braun[1], and Andreas Stute[1,2] — [1]Technische Hochschule Nürnberg Faculty AMP, Nürnberg, Germany — [2]Technische Hochschule Nürnberg Faculty EFI, Nürnberg, Germany

Single Nitrogen-Vacancy centers (NV-centers) in diamond can be operated at ambient conditions as qubits in quantum memories and nanoscale quantum sensors. At TH Nürnberg, we plan to deterministically generate single NV-centers via femtosecond-laser pulses and integrate them into photonic platforms via 3D-printed microoptics and fs-written waveguides. This presentation gives a summary about our activites: The design and analysis of micro-lens systems to be manufactured via Two-Photon Polymerization on top of individual, self-written NV-centers for increased photon-collection efficiency, the programming of a spatial light modulator for wavefront optimization, the setup of a confocal scanning fluorescence microscope that addresses individual NV-Centers and laser material processing that allows to shape the diamond surface and to fabricate waveguides in the diamond for efficient optical coupling.

Q 58.6 Thu 15:45 P 5

Towards large-scale characterization of color centers in diamond through automated photoluminescence excitation measurements — •Marie L. Sturm[1], Maarten H. van der Hoeven[1], Malo Bézard[1,2], Julian M. Bopp[1,2], and Tim Schröder[1,2] — [1]Department of Physics, Humboldt-Universität zu Berlin, 12489 Berlin, Germany — [2]Ferdinand-Braun-Institut (FBH), Gustav-Kirchhoff-Str. 4, 12489 Berlin, Germany

Spectrally indistinguishable single-photon emitters are a fundamental requirement for generating entanglement in photonic quantum networks. Identifying such emitters demands precise knowledge of their optical transition frequencies and linewidths.

We demonstrate a scalable characterization approach for color centers in diamond based on automated photoluminescence-excitation (PLE) spectroscopy. A large-scale characterization capability can be enabled by full automation of the experimental control, including tuning of a continuous-wave laser with MHz frequency precision. By exciting a large field of view rather than addressing individual emitters, the overall characterization throughput can be significantly enhanced.

Using this technique, we investigate the spectral homogeneity of tin-vacancy centers in diamond. This method enables identification of spectrally indistinguishable emitters for deterministic integration into quantum devices and is applicable to various solid-state platforms, paving the way for scalable on-chip quantum-photonic architectures.

Q 58.7 Thu 16:00 P 5

Creation and cavity coupling of a single SnV- center in nanodiamond — •Selene Sachero[1], Robert Berghaus[1], Florian Feuchmayr[1], Emilio Corte[2], Elena Nieto Hernandez[2], Jens Fuhrman[1], Sviatoslav Ditalia Tchernij[2], Fedor Jelezko[1], and Alexander Kubanek[1] — [1]Ulm university, Ulm, Germany — [2]Turin university, Turin, Italy

Efficient coupling between quantum emitters and optical cavities is essential for scalable quantum photonic technologies. Group IV vacancy centers in diamond, particularly the negatively charged tin-vacancy center, have emerged as promising candidates due to their spectral stability, high Debye-Waller factor and large orbital splitting in ground-states. Reduction of the diamond host size to the nanoscale enables new opportunities in terms of integration and scalability. However, creating optically coherent quantum emitters in nanodiamonds remains a major challenge. Here, we present the fabrication of tin- vacancy (SnV^-) centers by means of ion implantation and describe the optical properties of the created color centers. We achieve high-purity single-photon emission via resonant excitation and strong coherent drive. Moreover, we demonstrate controlled coupling of a single SnV^- center in a nanodiamond to a fully tunable Fabry-Perot microcavity. At 4 K, lifetime reduction due to the Purcell effect is achieved. The obtained results demonstrate the potential of SnV^- centers in nanodiamonds as a coherent single-photon source for quantum networks

Q 58.8 Thu 16:15 P 5

SiV color centers in diamond as Quantum Network Nodes — •Leonie Eggers[1,2], Donika Imeri[1,2], Konstantin Beck[1], Nick Brinkmann[1,2], Florian Rickert[1], Sunil Kumar Mahato[1,2], Rikhav Shah[1], and Ralf Riedinger[1,2] — [1]Zentrum für Optische Quantentechnologien, Universität Hamburg, 22761 Hamburg — [2]The Hamburg Centre for Ultrafast Imaging, 22761 Hamburg, Germany

Silicon vacancy color center(SiV) in diamond, when combined with nanophotonic cavities, are a promising platform for network-based quantum solid-state processors. This is due to their spin transition being photonically addressable and a high noise tolerance. Pairing these processors with a fiber network can enable efficient long-distance quantum communication. It also presents a modular approach to building larger quantum processors. Here we present our experimental platform and first results.

Q 59: QuanTour V – Protocols

Inspired by QuanTour, the traveling quantum-dot light source, the sessions QuanTour I-V focus on the physics of quantum light generation in solid-state systems and applications in quantum networks.

Time: Thursday 14:30–16:30 Location: P 7

Invited Talk Q 59.1 Thu 14:30 P 7

High-Speed Quantum Key Distribution using Single Photons from Defects in Hexagonal Boron Nitride — Furkan Ağlarci[1], Ömer S. Tapşin[1], Çağlar Samaner[1], Serkan Paçal[1], and •Serkan Ateş[1,2] — [1]Department of Physics, Izmir Institute of Technology, Izmir, Türkiye — [2]Faculty of Engineering and Natural Sciences, Sabanci University, Tuzla, Istanbul, Türkiye

We present an experimental demonstration of free-space Quantum Key Distribution (QKD) utilizing single photons generated from optically active defects in hexagonal boron nitride (hBN) operating at room temperature (RT). In our implementation of the B92 protocol, we successfully integrated the hBN single-photon source (SPS) with a resonant electro-optic modulator, enabling dynamic polarization encoding at a 40 MHz clock rate. This high-speed operation yielded a sifted key rate of 17.5 kbps and a secure key rate (SKR) of 7 kbps with a Quantum Bit Error Rate of 6.49%, representing one of the highest reported SKRs for a RT-SPS with active polarization modulation. We benchmark this performance against other quantum emitters and analyze the potential of hBN defects in a hypothetically secured BB84 framework. We show that with achievable improvements, such as microcavity coupling, the source has the potential to reach an SKR in the Mbps range. This work highlights the versatility and maturity of hBN defects as bright, RT-SPS, paving the way for practical, high-speed, and miniaturized quantum communication systems, including future space-based QKD missions.

Q 59.2 Thu 15:00 P 7

GHz-clocked Single-photon Quantum Key Distribution in the Telecom C-band — •Mareike Lach[1], Koray Kaymazlar[1], Robert B. Behrends[1], Lucas Rickert[1], Martin von Helversen[1], Jochen Kaupp[2], Yorick Raum[2], Tobias Huber Loyola[2,3], Sven Höfling[2], Andreas Pfenning[2], and Tobias Heindel[4] — [1]Institute of Physics and Astronomy, Technische Univeristät Berlin — [2]Technische Physik, Physikalisches Institut and Würzburg-Dresden Cluster of Excellence — [3]Karlsruher Institut für Technologie, Institute of Photonics and Quantum Electronics — [4]Department for Quantum Technology, Univeristät Münster

High speed operation is one of the most desired properties for implementations of quantum key distribution (QKD). This requires however the generation and state-preparation of photonic qubits at high speed. Here, we report on a QKD system based on the BB84 protocol that operates at GHz clock-rates using a highly Purcell-enhanced single-photons source emitting in the telecom C-band. We use a laser with a repetition rate of 2.5 GHz to pump the quantum dot source and prepare the polarization states fot the protocol using a customized fiber-based electro-optic modulator (EOM) controlled by an arbitrary waveform generator (AWG) using the trigger output of the pump laser as common clock. Our results show that our system performs the BB84 protocol succesfully with a quantum bit error ratio (QBER) around 5 % at these unprecendeted high clock-rates.

Q 59.3 Thu 15:15 P 7

Deployed entanglement-based BBM92 quantum key distribution using frequency-converted photons emitted by a quantum dot — •Michal Vyvlecka[1], Raphael Joos[1], Benjamin Breiholz[1], Aurélien Marmasse[1], Ilenia Neureuther[1], Timo Schnieber[1], Anna Frederike Köhler[1], Tim Strobel[1], Tobias Bauer[2], Marlon Schäfer[2], Nand Lal Sharma[3], Caspar Hofmann[3], Simone Luca Portalupi[1], Christoph Becher[2], and Peter Michler[1] — [1]Institut für Halbleiteroptik und Funktionelle Grenzflächen, Center for Integrated Quantum Science and Technology (IQST) and SCoPE, 70569 Stuttgart, Germany — [2]Fachrichtung Physik, 66123 Saarbrücken, Germany — [3]Institute for Integrative Nanosciences, 01069 Dresden, Germany

We implemented an entanglement-based BBM92 quantum key distribution (QKD) protocol over approximately 700 m across the university campus buildings using the existing deployed fiber network. The entangled-photon pair at wavelength of 780 nm was emitted by an epitaxially grown droplet-etched GaAs quantum dot (QD) embedded in a dielectric antenna. The QD was excited via two-photon excitation using a pulsed laser that emits 10 ps pulses at 779 nm with a 380 MHz repetition rate. To minimize losses in silica fibers, we employed bidirectional, polarization-conserving quantum frequency conversion to shift the QD emission to a telecom wavelength. We achieved stable QKD operation for more than 10 hours, with a raw key rate exceeding 200 Hz and a quantum bit error rate below 4.5 %. After error correction and privacy amplification, we distilled a secure key at a rate of 100 Hz.

Q 59.4 Thu 15:30 P 7

Experimental Quantum Strong Coin Flipping - An Application of QTorch — •Koray Kaymazlar[1], Daniel Vajner[1], Fenja Drauschke[2], Lucas Rickert[1], Martin von Helversen[1], Shulun Li[3], Zhichuan Niu[3], Anna Pappa[2], and Tobias Heindel[4] — [1]Institute of Physics and Astronomy, Technische Univeristät Berlin, Germany — [2]Electrical Engineering and Computer Science Department, Technische Univeristät Berlin, Germany — [3]Institute of Semiconductors, Chinese Academy of Sciences, Beijing, China — [4]Department for Quantum Technology, University of Münster, Germany

Strong coin flipping is a fundamental cryptographic protocol allowing two distrustful parties to agree on randomly generated bits. We report the first implementation of a quantum strong coin flipping using single photons and demonstrate a quantum advantage compared to both classical protocols and implementations using weak coherent pulses [1]. The quantum advantage is enabled by employing a state-of-the-art deterministic single-photon source from the same family of the one used in QuanTour outreach project based on a quantum dot embedded in a high-Purcell microcavity. Our QSCF implementation, operating at an 80 MHz clock-rate enables a coin flipping rate of 1.5 kHz and an average QBER below 3%, sufficient to realize a quantum advantage. [1] D. A. Vajner, K. Kaymazlar, F. Drauschke, L. Rickert, M. von Helversen, H. Liu, S. Li, H. Ni, Z. Niu, A. Pappa, T. Heindel, Single-Photon Advantage in Quantum Cryptography Beyond QKD, arXiv:2412.14993 (2024)

Q 59.5 Thu 15:45 P 7

Benchmarking quantum key distribution by mixing single photons and laser light — •Yann Portella[1], Petr Steindl[1], Juan Rafael Álvarez[1], Tim Hebenstreit[2], Aristide Lemaître[1], Martina Morassi[1], Niccolo Somaschi[3], Loïc Lanco[1], Filip Rozpedek[4], Pascale Senellart[1], and Dario A. Fioretto[1,3] — [1]Centre de Nanosciences et de Nanotechnologies, Université Paris-Saclay, CNRS, Palaiseau, France — [2]Max Planck Institute for the Science of Light, Erlangen, Germany — [3]Quandela SAS, Massy, France — [4]College of Information and Computer Science, University of Massachusetts Amherst, Amherst, Massachusetts, USA

Quantum key distribution stands out as a major application of quantum technologies, alongside quantum computing and quantum sensing. Many protocols require single photons, often approximated by dim laser pulses. Here, we propose a hybrid approach where the information is encoded with an incoherent mixture of single photons generated by a micropillar-embedded quantum dot and laser pulses. We show that there is an optimal mixture at any distance maximizing the secret key rate, benefiting both from the long distance scaling of single photons and high rate at short distance of laser light. This provides a flexible technology compensating for limited collected brightnesses of single-photon sources as well as a thorough investigation of advantage scenarios for single-photon and hybrid statistics. We highlight an efficiency threshold for unconditional advantage of single photons over laser light, and show insights on the interplay between single-photon purity and collected brightness in the performances of BB84.

Invited Talk Q 59.6 Thu 16:00 P 7

Metropolitan Quantum Key Distribution based on Room Temperature Single Photon Source — •Haoran Zhang — School of Electrical and Electronic Engineering, Nanyang Technological University, Singapore, Singapore

Quantum Key Distribution (QKD) is a cryptographic technology that supports the negotiation and sharing of private keys with unconditional security between authorized parties. As QKD scales to a global level, it must address performance limitations, high costs, and practical security concerns. For the deployment of QKD using single-photon sources (SPSs), existing demonstrations are still limited to operation at cryogenic temperatures. We realized the first demonstration of QKD based on a telecommunication-wavelength SPS operating at room temperature, as well as the first metropolitan-scale SPS-based QKD experiment at room temperature, paving the way for the commercial deployment of SPS-based QKD systems.

Q 60: Quantum Communication, Networks, Repeaters, & QKD II

Time: Thursday 14:30–16:30 Location: P 10

Invited Talk Q 60.1 Thu 14:30 P 10

Towards entangling distributed registers of atoms — •Ben Lanyon — Institut für Experimentalphysik, Universität Innsbruck, Technikerstasse 25, 6020 Innsbruck, Austria

We are developing methods to entangle remote registers of atoms over distances ranging from a few meters to hundreds of kilometers or more. Such distributed atomic quantum networks could enable new applications in sensing, timekeeping, computing, and communication, and are being pursued worldwide using a variety of approaches. Our approach employs network nodes that each consist of a register of electrically trapped atomic ions (calcium), integrated with an optical cavity for efficient atom-photon interaction, and a separate nonlinear optical process to convert ion emitted photons to telecom wavelengths. Full deterministic quantum logic is available on qubits encoded within the atomic register, allowing each node to function as a small-scale, photon interfaced quantum processor. In this talk, I will summarise one or two of our recently published results — including a photon interfaced ten qubit register of trapped ions [1] — or alternatively present some unpublished work, depending on progress in the months before the conference.

[1] M. Canteri et al., Photon interfaced ten qubit register of trapped ions, Phys. Rev. Lett. 135, 080801 (2025).

Q 60.2 Thu 15:00 P 10

Highly Indistinguishable Single Telecom Photons from a Tin-Vacancy-Center in Diamond — •David Lindler, Tobias Bauer, Dennis Herrmann, Robert Morsch, Marlon Schäfer, and Christoph Becher — Universität des Saarlandes, FR Physik, Campus E2.6, 66123 Saarbrücken

Tin-vacancy centers (SnV) in diamond are a promising platform for quantum nodes in quantum communication networks, exhibiting excellent optical and spin coherence [1,2]. To connect these nodes over long distances via optical fiber links, such as in a quantum repeater, it is necessary to first generate entanglement between each quantum node and a photon. The photons are then converted into the low-loss telecom C-band using quantum frequency down-conversion to mitigate the high losses associated with the visible wavelength of the SnV center photons. Performing a Bell-state measurement on the photons enables entanglement swapping, resulting in a pair of entangled remote quantum nodes. Achieving a quantum-repeater advantage over direct transmission requires the photons to be highly indistinguishable to ensure successful Bell-state measurements with high fidelity.
We present the generation of highly indistinguishable photons in the telecom band that are emitted sequentially by a single SnV center. The indistinguishability of the photons, measured via Hong-Ou-Mandel interference, reaches a visibility of over 95% before, and over 90% after frequency conversion to the telecom C-band, respectively.

[1] J. Görlitz et al., npj Quant. Inf. 8, 45 (2022).
[2] I. Karapatzakis et al., Phys. Rev. X 14, 031036 (2024).

Q 60.3 Thu 15:15 P 10

Quantum repeater segment based on trapped ions with telecom interface — •Max Bergerhoff, Pascal Baumgart, Jonas Meiers, Christian Haen, Tobias Bauer, Christoph Becher, and Jürgen Eschner — Universität des Saarlandes, Experimentalphysik, 66123 Saarbrücken, Germany

The quantum repeater (QR) segment enables the connection between distant quantum computers and is, as part of a QR link [1], a fundamental building block for the realization of large-distance quantum networks. By dividing a transmission link in segments and cells [2], it is possible to overcome the exponential attenuation of direct transmission. To reduce losses, the photonic channel must operate at telecom wavelength.

We report on the implementation of a QR segment with free-space coupled photons from two $^{40}Ca^{+}$ ions in the same Paul trap as quantum memories. Atom-photon entanglement is generated [3] by controlled emission of single 854-nm photons from the ions after excitation with nanosecond laser pulses and separate single-mode fiber coupling. Atom-atom entanglement is then generated by a photonic Bell-state measurement after conversion of the 854 nm photons to 1550 nm. In this context, the perspective of a heterogeneous QR segment using a trapped $^{40}Ca^{+}$ ion and a SnV color center in diamond is discussed.

[1] P. van Loock et al., Adv. Quantum Technol., 3: 1900141 (2020).
[2] M. Bergerhoff et al., Phys. Rev. A 110, 032603 (2024).
[3] M. Bock et al., Nat. Commun. 9, 1998 (2018).

Q 60.4 Thu 15:30 P 10

The influence of back-decays on the indistinguishability of single Raman photons — •Pascal Baumgart, Max Bergerhoff, Jonas Meiers, Stephan Kucera, and Jürgen Eschner — Universität des Saarlandes, Experimentalphysik, 66123 Saarbrücken, Germany

The ability to generate indistinguishable single photons capable of high-contrast Hong-Ou-Mandel (HOM) interference is the keystone for implementing entanglement swapping protocols based on photonic Bell state measurements, which may be used to realise quantum repeater schemes [1] or connect quantum processing units in distributed quantum computing [2]. One method to generate single photons is laser excitation of a Raman transition with a stable ground state and a short-lived excited state that decays to a third meta-stable state under the emission of a Raman photon. However, the indistinguishability of these photons is influenced by the possibility of back-decay to the ground state and subsequent re-excitation on the driven transition, which broadens the photonic temporal wave packet beyond the Fourier limit [3]. We investigate this behavior for trapped $^{40}Ca^{+}$ ions using few-nanosecond excitation pulses. Numerical simulations identify the mean number of back-decays as a measurable quantity that correlates with achievable HOM visibility. This is supported by experimental data.

[1] P. van Loock et al., Adv. Quantum Technol. 3, 1900141 (2020)
[2] J. O'Reilly et al., Phys. Rev. Lett. 133, 090802 (2024)
[3] P. Müller et al., Phys. Rev. A 96, 023861 (2017)

Q 60.5 Thu 15:45 P 10

Long-distance quantum communication sending single photons and keeping many — •Stefan Häussler and Peter van Loock — Institute of Physics, Johannes Gutenberg-Universität Mainz, Staudingerweg 7, 55128 Mainz, Germany

We describe all-optical memory-based quantum repeaters for long-distance quantum communication, with memories realized in the form of fiber loops located in the repeater stations. The memories can be used to store components of logical Bell states encoded in quantum error correction codes and offer the possibility of performing teleportation-based error correction. By sending only single-photon states through the fibers connecting the stations, such repeaters can operate in the long-segment regime compatible with existing fiber-based communication infrastructure. We analyze the performance of our scheme for the Gottesman-Kitaev-Preskill code, including a concatenation with the Steane code, as well as the Quantum Parity Code, identifying operational regimes for total distances up to 10000km.

Q 60.6 Thu 16:00 P 10

Advanced Quantum Communication and Quantum Networks - From basic research to future applications — Björn Kubala, Alexander Sauer, •Alessandro Tarantola, and Matthias Zimmermann — German Aerospace Center (DLR), Institute of Quantum Techologies, Wilhelm-Runge-Straße 10, Ulm, 89081, Germany

The fast and reliable global classical communication enabled by the birth of the Internet brought about a cultural, economic and social

revolution, and opened the door to previously unthinkable applications. Many observers believe a similar revolution is bound to take place, once the Quantum Internet, coherently connecting quantum devices (sensors, computers, memories,...), is established. In this talk, we provide an overview of concrete distributed quantum applications, mainly in the field of quantum security, that will be made feasible by the rise of the Quantum Internet. Moreover, we argue that the theoretical investigation of distributed quantum protocols is crucial in steering the next hardware- and infrastructure-development steps.
This talk is based on joint work within the "Physikalische Grundlagen der Quanteninformation, -kommunikation und -verarbeitung" project.

Q 60.7 Thu 16:15 P 10

Connecting Neutral-Atom Quantum Nodes across a metropolitan fiber link — •Tobias Frank[1], Pooja Malik[2], Maya Büki[1], Gianvito Chiarella[1], Florian Fertig[2], Yiru Zhou[2], Pau Farrera[1,3], Harald Weinfurter[1,2], and Gerhard Rempe[1] — [1]Max Planck Institute of Quantum Optics, Garching, Germany — [2]Ludwig-Maximilians-University, Munich, Germany — [3]Munich Center for Quantum Science and Technology (MCQST), Munich, Germany

Neutral atoms are promising candidates for quantum networking due to their long coherence times, uniform optical transitions, and efficient light-matter interfaces. A central challenge is distributing high-fidelity entanglement between remote network nodes over metropolitan fiber links, where loss and environmental noise are significant.

We address this by interconnecting two neutral-atom quantum nodes via a 23.7 km deployed telecom fiber link in the Munich metropolitan area. Using active polarization stabilization and quantum frequency conversion to the telecom S-band at the sender, we distribute atom-photon entanglement with minimal transmission loss. At the receiver, telecom photons are back-converted to 780 nm and stored in a passively heralded memory, providing a low-noise indication of successful storage. With Spin-echo techniques we extend the memory coherence time, while using microwave qubit rotations combined with fluorescence-based detection we can enhance the readout efficiency, both essential requirements for high-fidelity entanglement distribution between the two distant nodes.

Q 61: Matter Wave Interferometry and Metrology III

Time: Thursday 14:30–16:30 Location: P 11

Q 61.1 Thu 14:30 P 11

Electron induced Raman interferometry with 'large' mass particles — •Christian Vogt — BIAS - Bremer Institut für angewandte Strahltechnik GmbH

General relativity and quantum mechanics provide two highly successful yet fundamentally incompatible descriptions of nature for different parameter regimes. An important frontier in modern physics is therefore to design experiments that operate in areas where both may simultaneously influence the dynamics. Experiments where one could measure the gravitational attraction from a quantum object are impossible for now but steady progress has been made by preparing increasingly massive objects in quantum states, typically demonstrated through interference.
Matter-wave interferometers have been realized for electrons, atoms, and complex molecules, with the current mass record around 25 kDa. A promising platform for pushing these limits further is levitated optomechanics, where silica nanoparticles are trapped under high-vacuum conditions and their center-of-mass motion can be cooled to the motional ground state. Since the associated wave packets are only on the picometer scale, current efforts focus on wave function expansion, for example in inverted gaussian or other nonlinear potentials.
We propose a different strategy, where the particles are forced into superposition states by entangling them via coulomb interaction with an electron in superposition. In the talk we will present promising theoretical results on the feasibility of such experiments well beyond the current mass record.

Q 61.2 Thu 14:45 P 11

A compact, highly stable dual-laser system for quantum logic spectroscopy of $^{27}Al^{+}$ — •Gayatri R. Sasidharan[1,2], Sofia Herbers[1], Constantin Nauk[1,2], Joost Hinrichs[1,2], Fabian Dawel[1], Benjamin Kraus[1], and Piet O. Schmidt[1,2] — [1]Physikalisch-Technische Bundesanstalt, 38116 Braunschweig, Germany — [2]Leibniz Universität Hannover, Institut für Quantenoptik, 30167 Hannover, Germany

Optical clocks using trapped $^{27}Al^{+}$ reach a fractional frequency uncertainty below 10^{-18} [1]. For coherent manipulation of trapped ions, lasers with long coherence time and narrow linewidth are needed. The best stationary laser systems reach an instability of 4 x10^{-17} [2] and transportable systems 1.6 x 10^{-16} [3]. This is achieved by stabilizing the laser frequency to a optical cavity. A dual wavelength coated optical cavity is a practical solution addressing space limitations in transportable setups. In this talk, we present a compact, highly-stable dual-laser system for quantum logic spectroscopy. The 729 nm and 1068 nm transitions on $^{27}Ca^{+}$ and $^{27}Al^{+}$, respectively, are needed to perform quantum logic spectroscopy on the clock ion $^{27}Al^{+}$. We report on photothermal and vibrational noise affecting the instability of the cavity. This work shows that a dual wavelength coating can be used for highly stable laser applications making it viable tool for precision spectroscopy experiments.

[1] Marshall, et al., PRL 135, 033201 (2025)
[2] D. G. Matei, et al., PRL 118, 263202 (2017)
[3] S. Herbers, Opt. Lett., OL 47, 5441-5444 (2022)

Q 61.3 Thu 15:00 P 11

Heterodyne cavity-tracking for enhanced displacement sensing — •Nurmi Sawlanski, Shreevathsa Chalathadka Subrahmanya, and Oliver Gerberding — Institute of Experimental Physics, University of Hamburg, 22761 Hamburg, Germany

Gravitational-wave detectors allow us to observe compact binaries and other extreme astrophysical events by measuring minute changes in the distance between nominally free-falling test masses. To separate these signals from seismic motion and technical disturbances, the detectors rely on ultra-sensitive displacement sensors in their active isolation and control systems. Improving such sensors is therefore essential for future gravitational-wave observatories.

Heterodyne cavity-tracking is a laser interferometric displacement readout scheme that enables sub-femtometer precision with an operating range on the order of a wavelength. A laser is locked to the resonance of a cm-scale cavity containing the proof mass, and the resulting frequency changes are measured via a heterodyne beat with a second, stable laser using a GHz-bandwidth phasemeter. This combines high precision with a dynamic range suitable for tracking test-mass motion.

Our fiber-based setup has achieved a displacement sensitivity of about 20 fm/$\sqrt{\text{Hz}}$ for frequencies above 5 Hz and a dynamic range of six orders of magnitude by tracking motions up to 0.15 μm. To further improve the achievable sensitivity, we plan to implement Pound-Drever-Hall locking for laser stabilization and to move to a free-beam vacuum setup. In this talk, we present the sensing scheme, current performance, and planned experimental steps.

Q 61.4 Thu 15:15 P 11

Ramsey-Bordé Interferometry with a Thermal Strontium Beam for a Compact Optical Clock — •Oliver Fartmann[1], Marc Christ[2], Amir Mahdian[1,2], Levi Wihan[1], and Markus Krutzik[1,2] — [1]Humboldt-Universität, Inst. f. Physik, Newtonstr. 15, 12489 Berlin — [2]Ferdinand-Braun-Institut (FBH), Gustav-Kirchhoff-Straße 4, 12489 Berlin

Compact optical clocks based on Ramsey-Bordé interferometry (RBI) with a thermal atomic beam offer higher stability than optical vapour cell clocks while being less complex than cold atom clocks.

This talk presents the realization of strontium RBI on the narrow $^1S_0 \rightarrow {}^3P_1$ intercombination line at 689 nm. A structured optimization of major subsystems was carried out, including clock-laser pre-stabilization to a high-finesse cavity, successive improvements to the atomic oven, spectroscopy-based error-signal generation, feedback loop, and a systematic evaluation of clock stability limitations.

Our first operating RBI-clock demonstrated fractional frequency instabilities below $\sigma_y(\tau) < 10^{-13}$ for averaging times between 1 s and 1000 s, with residual temperature fluctuations identified as the dominant limitation. Building on these results, two additional portable RBI spectroscopy setups were developed, with volumes of only 20 l. Initial instability measurements and the uncertainty budget will be presented.

These systems serve as ground-based demonstrators and testbeds, paving the way for mobile and space-deployable optical clocks.

[1] O. Fartmann et al. EPJ Quantum Techn. 12, 31 (2025).

Q 61.5 Thu 15:30 P 11

Exploring few-shot quantum metrology with photonic qubits — •Lukas Rückle[1,2] and Stefanie Barz[1,2] — [1]Institute for Functional Matter and Quantum Technologies, University of Stuttgart, 70569 Stuttgart, Germany — [2]Center for Integrated Quantum Science and Technology (IQST)

The use of quantum states for metrology tasks has been proven to surpass classical precision limits for the estimation of parameters. Recently, the framework of *probably approximately correct (PAC) metrology* has been introduced. It not only enables the estimation of a parameter in an arbitrarily big parameter space without prior knowledge, but also gives bounds for few- and single-shot metrology settings. It thus bridges the rather theoretical case of performing infinitely many measurements and practical metrology tasks.

Here, we present experimental results in a photonic metrology setting. We show how to use different states and measurements and how for each case to optimize the prediction strategy of the parameter that shall be estimated. Our work shows how to implement the given new framework of PAC metrology and thus helps improving the precision of applications that only allow for a few measurements, e.g. when measuring fast varying systems.

Q 61.6 Thu 15:45 P 11

Phase reconstruction for lattice-confined cold atoms from matter-wave interference measurements — •Niklas Euler[1], Justus Brüggenjürgen[2], Christof Weitenberg[3], and Martin Gärttner[1] — [1]IFTO, FSU Jena, Max-Wien-Platz 1, 07743 Jena, Germany — [2]IQOQI, Technikerstraße 21a, 6020 Innsbruck, Austria — [3]TU Dortmund, Otto-Hahn-Straße 4a, 44227 Dormund, Germany

In recent years, cold-atom experiments with single-site imaging have become state of the art in matter-wave microscopy, providing unrivaled resolution in position-space measurements. However, achieving similar resolution in different measurement bases has remained challenging for lattice-confined atoms, restricting access to general microscopic state properties. Of special importance to several research avenues is the determination of the phase structure of a quantum state, with previous proposals working only in the regime of weak phase fluctuations. Here, we propose a novel scheme for the reconstruction of quantum phases using only high-precision density measurements after short time evolution, exploiting the sensitivity of the emerging interference pattern with respect to the phases. Our method decomposes the quantum state into local modes that are individually evolved in time, transforming the phase reconstruction into a set of low-dimensional optimization problems with overall linear scaling in the system size. To demonstrate its effectiveness, we applied our method to both synthetic and experimental data and find a generally high reconstruction quality and remarkable robustness to common experimental noise sources.

Q 61.7 Thu 16:00 P 11

Thermal qualification of an atom chip vacuum system — •Markus Trost and Maike Diana Lachmann — Airbus Defence and Space GmbH, Willy-Messerschmitt-Strasse 1, 82024 Taufkirchen, Gernamy

Matter-wave interferometry with ultra-cold atomic ensembles has developed as a promising prospect for acceleration measurements leading to increased long-term stability. Placing such sensors on satellites, offers a variety of application cases such as gravimetry on a global scale, testing fundamental physics or using it to detect drifts of satellites. However, this kind of sensor requires several prerequisites like for example magnetic field creation or an ultra-high vacuum system to generate an ultra-cold ensemble of atoms. While this technology is already well proven on ground-based setups, sounding rockets and the ISS, there has not yet been a dedicated standalone satellite mission for such a system. Particularly the qualification for the unstable thermal conditions on a satellite platform has not been performed yet. Therefore, the Cold Atom Interferometry Vacuum System (CAIVAS) project was initiated by ESA. Within this project, an atom-chip ultra-high vacuum system made for space-based usage is designed and realized. Thermal requirements were defined and subsequently verified. The results of the study will be presented in this talk.

Q 61.8 Thu 16:15 P 11

Concurrent atom interferometry for in situ beam characterization — •Christian Struckmann, Knut Stolzenberg, Daida Thomas, Ernst M. Rasel, Dennis Schlippert, and Naceur Gaaloul — Leibniz University Hannover, Institute of Quantum Optics, Welfengarten 1, 30167 Hannover, Germany

Quantum sensors based on the interference of matter waves provide a highly sensitive and stable measurement tool for inertial forces with applications in geodesy, navigation, and fundamental physics. One of the leading systematic effects limiting the sensitivity of state-of-the-art atom interferometers is wavefront aberrations. Residual curvature and higher-order distortions of the interrogation beams imprint spatially varying phases across the atomic ensemble, leading to systematic biases. Conventional optical diagnostics only partially capture these effects and do not reflect the in situ, atom-averaged response. This motivates direct, atom-based characterization of the interrogation fields to push the limits of accuracy and robustness.

In this contribution, we present the application of PIXL (Parallelized Interferometers for XLerometry), a novel method to operate a quantum sensor based on a 2D array of Bose-Einstein condensates, to the 3D characterization of the interrogation beam's wave vector and intensity profiles [Stolzenberg et al., Phys. Rev. Lett. 134, 143601 (2025)].

Q 62: Ultra-cold Atoms, Ions and BEC IV (joint session A/Q)

Time: Thursday 14:30–16:30 Location: N 1

Q 62.1 Thu 14:30 N 1

Stability of current-carrying Bose-condensed states in a hard-core Bose-Hubbard model with long-range hopping — •Yoshihiro Yabuuchi[1,2] and Ippei Danshita[2] — [1]Osaka Metropolitan University, Japan — [2]Kindai University, Japan

The technological progress in the platforms for long-range interacting spin systems have opened new possibilities for exploring emergent quantum many-body phenomena arising from the long-range nature of interactions. Rydberg atom arrays and trapped ions have allowed for realizing systems described by the spin-1/2 XY model with long-range spin-exchange interactions, in which the coupling strength decays algebraically as $\propto r^{-\alpha}$, where r is the distance between sites and α the decay exponent. Owing to the theoretical mapping between the spin-1/2 XY model and the hard-core Bose-Hubbard model, the long-range interaction in the former corresponds to the long-range hopping of hard-core bosons where the hopping amplitude decays as $\propto r^{-\alpha}$. We theoretically investigate how the long-range hopping affects the stability of current-carrying Bose-condensed states of hard-core bosons [1]. Within a mean-field theory, we find that the critical quasi-momenta for both Landau and dynamical instabilities decrease with decreasing α from a large value and vanishes at $\alpha = 3$, implying that long-range hopping reduces the stability of the current-carrying state. Near $\alpha = 3$, the critical quasi-momentum for the dynamical instability is proportional to $\Delta^{1+\Delta}$ with $\Delta = \alpha - 3$, meaning that the scaling exponent itself depends on Δ as a remarkable consequence of the long-range nature. [1] Y. Yabuuchi, and I. Danshita, arXiv:2511.14260

Q 62.2 Thu 14:45 N 1

Quantum bubbles in the Einstein-Elevator facility at Leibniz University Hannover — •Charles Garcion[1], Timothé Estrampes[1], Brendan Rhyno[1], Jean-Baptiste Gérent[2], Eric Charron[3], Ernst Maria Rasel[1], Nathan Lundblad[2], and Naceur Gaaloul[1] — [1]Institute of Quantum Optics, Leibniz University Hannover,Welfengarten 1, 30167 Hanover, Germany — [2]Department of Physics and Astronomy, Bates College, Lewiston, ME, USA. — [3]Institut des Sciences Moléculaires d'Orsay, CNRS, Université Paris-sacay, F-91405, Orsay, France

Quantum bubbles atoms confined to a closed surface offer a unique platform for studying topological phenomena, including vortex dynamics and collective modes on curved manifolds. Creating these potentials requires RF-dressed states, where the direct interaction between atoms and the RF field makes the system highly sensitive to source noise. The Quantumania project targets these geometries using the MAIUS-1 payload in the Einstein-Elevator at Leibniz University Hannover. To ensure sufficient field quality, we have initiated the design of a custom RF source specifically to minimize heating and noise. We present the technical specifications of this new source and our strategy for antenna optimization. These efforts aim to achieve robust atom dressing in the Einstein-Elevator. Furthermore, characterizing these bubble potentials contributes to the optimization of experimental schemes within our collaboration with the Cold Atom Laboratory on the International Space Station.

Q 62.3 Thu 15:00 N 1

Hilbert space fragmentation in driven-dephasing Rydberg atom array — tianyi yan, chunhei leung, and •weibin li — University of Nottingham, Nottingham NG7 2RD, United Kingdom

We investigate the onset and mechanism of Hilbert space fragmentation (HSF) in a chain of strongly interacting Rydberg atoms subject to local dephasing. It is found that the emergence of multiple long-lived metastable states is fundamentally tied to HSF of the driven-dephasing Rydberg atom system. We demonstrate that the manifesting HSF is captured by a dephasing PXP model that supports multiple degenerate zero modes. These modes form disconnected, block-diagonal subspaces of maximally mixed states, which consist of many-body spin states sharing the same symmetry. A key result is the identification of the underlying symmetry in the HSF, where conserved quantities in each subspace are defined by the consecutive double excitation addressing operator. Moreover, we show explicitly that the number of the fragmented Hilbert space grows exponentially with the chain length, following a modified Fibonacci sequence. Our work provides insights into many-body dynamics under dynamical constraints and opens avenues for controlling and manipulating HSF in Rydberg atom systems.

Q 62.4 Thu 15:15 N 1

Discovery of atomic Shapiro steps — •Vijay Singh[1], E. Bernhart[2], M. Röhrle[2], H. Ott[2], G. Del Pace[3], D. Hernandez-Rajkov[3], N. Grani[3], M. Frometa Fernandez[3], G. Nesti[3], J. A. Seman[4], M. Inguscio[3], G. Roati[3], L. Mathey[5], and L. Amico[1] — [1]QRC,TII,AbuDhabi, UAE — [2]RPTU Kaiserslautern, Germany — [3]LENS, University of Florence, Italy — [4]UNAM Mexico — [5]ZOQ and IQP, Universität Hamburg, Germany

I will discuss how Josephson effects arise in ultracold quantum systems and present recent theoretical predictions for driven atomic Josephson junctions [1]. Following this proposal, two leading experimental groups worldwide have independently observed Shapiro steps in atomic junctions for the first time [2, 3]. These experiments demonstrate deterministic, phase-locked transport in atomic circuits. Together, these advances establish driven atomic Josephson junctions as a versatile platform for atomtronics, quantum simulation, and quantum technology development.

[1] Singh, Polo, Mathey, Amico, PRL 133, 093401 (2024)

[2] Del Pace, Hernandez-Rajkov, Singh, Grani, Fernandez, Nesti, Seman, Inguscio, Amico, Roati, arXiv: 2409.03448 (2024)

[3] Bernhart, Röhrle, Singh, Mathey, Amico, Ott, arXiv: 2409.03340 (2024)

Q 62.5 Thu 15:30 N 1

Bayesian Thermometry with Single-Atom Quantum Probes for Ultracold Gases — •Julian Fess, Luca Granert, Sabrina Burgardt, Silvia Hiebel, and Artur Widera — Department of Physics, University of Kaiserslautern-Landau, Germany

Quantum probes are atomic sized devices mapping information of their environment to quantum mechanical states. By improving measurements and at the same time minimizing perturbation of the environment, they form a central asset for quantum technologies. We experimentally realize spin-based quantum thermometers by immersing individual Cs atoms into an ultracold Rb bath. Controlling inelastic spin-exchange processes between the probe and bath allows us to map motional and thermal information onto quantum-spin states. We find that the information gain per inelastic collision can be maximized by harnessing the nonequilibrium spin dynamics. The parameters that need to be tuned to achieve maximum information gain depend on the temperature being estimated, making this system well-suited for Bayesian estimation strategies. In this work, we compare three protocols: unoptimized, a priori optimized, and adaptively optimized. These protocols are evaluated based on their convergence speed and the magnitude of the estimation error. Among them, the adaptive protocol performs best, as it dynamically adjusts the parameters to optimize the information gained from each measurement. This approach highlights the potential of leveraging nonequilibrium dynamics to optimize measurement strategies, paving the way for more efficient and precise quantum thermometry.

Q 62.6 Thu 15:45 N 1

Vortices in a 2D fermionic superfluid — •Hans Leonard Michel, Artak Mkrtchyan, Moritz von Usslar, René Henke, Cesar Cabrera, and Henning Moritz — Institut für Quantenphysik, Universität Hamburg, Hamburg, Germany

Quantised vortices are widely studied excitations in superfluid systems from helium to ultracold Bose Einstein condensates. While many experiments observed vortices in 3D systems, few realisations were made in 2D systems and none in the 2D BEC-BCS crossover. Here, we will report on the deterministic creation and observation of vortices and their phase quantisation in homogeneous 2D ultracold Fermi gases.

We prepare the homogeneous 2D disk shaped systems by freezing out the vertical motion and imposing a circular outer radial barrier. The vortices are detected by ramping to a quasi-3D regime and subsequent time of flight imaging. This method allows us to reliably create and detect single vortex anti-vortex pairs as well as doubly charged vortices across the BEC-BCS crossover. We confirm that these vortices are quantised by observing the phase profile using matter wave interferometry. To this end, we let the central disk shaped region interfere with an annular outer gas as phase reference after ramping to 3D. Our observation of concentric rings and spirals with one or two arms when creating vortices with no, single or double charge confirms the quantisation of the phase of the vortex. Our measurements provide proof of phase coherence and strong evidence for superfluidity in these strongly interacting quantum fluids across the BEC-BCS crossover.

Q 62.7 Thu 16:00 N 1

Extended Gross-Pitaevskii equation for quantum droplets in cavity BEC systems — •Leon Mixa[1,2,3], Laurenz Timmermann[1], Milan Radonjić[1,4], Axel Pelster[3], and Michael Thorwart[1,2] — [1]I. Institut für Theoretische Physik, Universität Hamburg, Germany — [2]The Hamburg Center for Ultrafast Imaging, Hamburg, Germany — [3]Physics Department and Research Center OPTIMAS, Rheinland-Pfälzische Technische Universität Kaiserslautern-Landau, Germany — [4]Institute of Physics Belgrade, University of Belgrade, Serbia

Quantum droplets are an exotic state of matter that characterizes a self-bound many-body system emerging from quantum fluctuation energy corrections to the ground state. Here, we present a theoretical framework for a new type of quantum droplet that emerges from a Bose-Einstein condensate in a cavity. Vacuum fluctuations in the cavity mediate an effective, long-range atom-atom interaction that, at the leading order, results in the formation of a distinct roton mode. The zero-point energy of the roton increases proportionally to the volume of the atom gas and thus competes with the repulsive s-wave contact interaction, facilitating the formation of the droplet [PRR 7, 033216; PRR 7, 023204 (2025)]. We present an extended Gross-Pitaevskii equation for the ground state incorporating the quantum fluctuation contribution. We analyze the impact of the roton mode correction term on the droplet wave function. Using a variational ansatz, we evaluate the stability, size, and density of the droplet, comparing it to the homogeneous density profile used in the original derivation.

Q 62.8 Thu 16:15 N 1

Analytical approach to collisional decoherence in a BEC double-well accelerometer — •Kateryna Korshynska[1,2] and Sebastian Ulbricht[1,2] — [1]PTB Braunschweig — [2]TU Braunschweig

Modern quantum sensors provide a way to measure accelerations and gravitational fields to tremendous precision, surpassing their classical counterparts. One way to build such a quantum sensor is to exploit the process of quantum tunneling of a Bose-Einstein condensate (BEC), trapped in a double-well potential. This tunneling emerges as the collective oscillations of particles between the wells, which are usually referred to as Josephson oscillations. They rely on the coherence between the quantum states of each well, which can decrease due to collisional decoherence. For the weakly-interacting gas, we analytically describe this decoherence process with the density matrix approach and show how the Josephson oscillations decay with time. Further, we consider the BEC subject to external acceleration and find that the interplay between the acceleration and collisions leads to an additional shift of the oscillation frequency. Moreover, we study how this effect can be used as the basis of a BEC double-well accelerometer and estimate its expected sensitivity.

Q 63: Precision Spectroscopy of Atoms and Ions V (joint session A/Q)

Time: Thursday 14:30–16:30 Location: N 3

Q 63.1 Thu 14:30 N 3

Indium multi-ion clock operation and investigations of ground state cooling — •Shobhit Saheb Dey[1], Ingrid Maria Richter[1], Mouhamed-Omar Manai[1], Hartmut Nimrod Hausser[1], Dongliang Cong[1], Jonas Keller[1], and Tanja E. Mehlstäubler[1,2] — [1]Physikalisch-Technische Bundesanstalt, Braunschweig — [2]Institut für Quantenoptik, Leibniz Universität Hannover

Optical clocks based on trapped ions are pushing forward the limits of time and frequency metrology with systematic uncertainties approaching the low 10^{-19} range, while their stability stays fundamentally limited by the Quantum Projection Noise(QPN). Uncorrelated parallel interrogation of N ions is expected to scale down the QPN limited instability by $1/\sqrt{N}$. We establish this scaling up to 8 ions in a $^{115}In^+ - ^{172}Yb^+$ Coulomb crystal clock interrogating the $^1S_0 - ^3P_0$ clock transition of $^{115}In^+$ and Doppler cooling via $^{172}Yb^+$ ions. Thermal motion of ions at Doppler temperature causes a time-dilation (TD) shift, which is among the largest contributors to the systematic-uncertainty budget in the ion based clocks today.

Thus, we are currently investigating ground state cooling of Coulomb crystal with tens of ions using the 360 kHz wide $^1S_0 - ^3P_1$ intercombination line in $^{115}In^+$. This is expected to reduce relative shifts due to the TD to low-10^{-19} regime and we can spectroscopically measure the TD shift via interleaved clock operation.

Q 63.2 Thu 14:45 N 3

Hyperfine-induced state-dependent lifetime quenching on the $^2S_{1/2} \rightarrow {}^2F_{7/2}$ elctric octupole transition in ^{173}Yb$^+$ — •Ikbal A. Biswas[1], Jialiang Yu[1], Anand Prakash[2], Clara Zyskind[1], Rattakorn Kaewuam[3], Piyaphat Phoonthong[3], and Tanja E. Mehlstäubler[1,2] — [1]Physikalisch-Technische Bundesanstalt (PTB), Braunschweig, Germany — [2]Institut für Quantenoptik, Leibniz Universität Hannover, Hannover, Germany — [3]National Institute of Metrology (Thailand), 3/4-5 Moo 3, Klong 5, Klong Luang, 12120 Pathumthani, Thailand

We report the coherent excitation of the highly forbidden $^2S_{1/2} \rightarrow {}^2F_{7/2}$ clock transition in the odd isotope $^{173}Yb^+$ with nuclear spin $I = 5/2$. The measured lifetimes of the $F_e = 2, 3, 4$ hyperfine states are shorter than the unperturbed $^2F_{7/2}$ clock state of $^{171}Yb^+$ due to hyperfine-induced electric dipole decay channel. This reduced lifetime lowers the required optical power for coherent excitation of the clock transition, thereby reducing the AC Stark shift caused by the clock laser. Using a 3-ion Coulomb crystal, we experimentally demonstrate suppression of the AC Stark shift, a critical improvement for the scalability of future multi-ion Yb^+ clocks. Furthermore, we report the the measured hyperfine splitting and calculated quadratic Zeeman sensitivities of the $^2F_{7/2}$ clock state. Our results pave the way toward multi-ion optical clocks based on $^{173}Yb^+$.

Q 63.3 Thu 15:00 N 3

Shelving Spectroscopy of ground state ultraviolet transitions in dysprosium — •Kevin Ng[1], Paul Uerlings[1], Fiona Hellstern[1], Jens Hertkorn[1], Luis Weiss[1], Stephan Welte[1,2], Tilman Pfau[1], and Ralf Klemt[1] — [1]5. Physikalisches Institut and Center for Integrated Quantum Science and Technology IQST, Universität Stuttgart — [2]CZS Center QPhoton

The open inner-shell electronic structure of lanthanides with large magnetic moments gives rise to a rich spectrum of transitions available for laser cooling, trapping and coherent control of dipolar atoms. Despite this, the large number of ultraviolet (UV) transitions that exist below 400 nm in these atoms have so far been rarely utilized. Here, we investigate multiple ground state UV transitions in dysprosium. Many of these transitions have decay strengths to the ultralong-lived, low-lying first excited state that are comparable to the strongest transitions commonly used in dipolar gas experiments. Using shelving spectroscopy which improves detection sensitivity and provides a straightforward way to distinguish the numerous isotope and hyperfine transitions, we measure isotope shifts, hyperfine coefficients and create King plots to determine their electronic nature. Such knowledge of these UV transitions, which analogously exist in other magnetic atoms is important for optically populating the first excited state and can be used for creating an optical clock, high resolution imaging in quantum gas microscopy and probing lanthanide nuclei with enhanced Schiff moments in searches for physics beyond the standard model.

Q 63.4 Thu 15:15 N 3

MMC Array to Study X-ray Transitions in Muonic Atoms — •Hendrik Hadenfeldt for the QUARTET-Collaboration — Kirchhoff-Institute for Physics, Heidelberg University, Germany

The QUARTET collaboration aims to improve the accuracy of absolute nuclear charge radii of light nuclei from Li to Ne using high-precision X-ray spectroscopy of muonic atoms. A measurement with isotopically pure oxygen and copper has recently been performed at the Paul-Scherrer-Institute (PSI). Conventional solid-state detectors do not provide sufficient accuracy in the relevant energy range around 120 keV. Therefore, we use a low-temperature Metallic Magnetic Calorimeter (MMC). MMCs are characterized by a high resolving power of several thousand and a high quantum efficiency for the energy range of interest using 100 μm thick absorbers. In this talk, we present a newly developed MMC detector. First preliminary spectra and systematic effects observed in the measurement are discussed. The acquired data, together with the achieved energy resolution of better than 50 eV FWHM at 120 keV, enable a more precise characterization of muonic X-ray lines. In addition, we present the world's first compositional study of a prehistoric human tooth using high-precision X-ray spectroscopy of muonic atoms.

Q 63.5 Thu 15:30 N 3

High-Precision Spectroscopy of Single Molecular Hydrogen Ions in a Penning Trap at ALPHATRAP — •P. Justus[1], M. Bohman[1], A. Gramberg[1], F. Heisse[1], I. Kortunov[2], V. Vogt[2], C. König[1], K. Blaum[1], S. Schiller[2], and S. Sturm[1] — [1]Max-Planck-Institut für Kernphysik, Heidelberg — [2]Institut für Experimentalphysik, Universität Düsseldorf, Düsseldorf

Molecular hydrogen ions are the simplest molecules and thus ideal systems for testing QED through comparison of high-precision measurements with theoretical predictions [1]. At ALPHATRAP we measured for the ro-vibrational ground state of HD^+ the bound-electron g-factor to 0.20 ppb precision and the spin-interaction coefficients with 44 ppb and 151 ppb uncertainty [2], which can be compared to *ab initio* theory [3]. In a next step, we carried out high-precision laser spectroscopy of ro-vibrational levels via driving the $0 \rightarrow 5$ vibrational transition in HD^+.

We will present conclusions drawn from our measurements and planned refinements that will, in the future, provide a versatile platform for ultra-high precision laser spectroscopy - particularly of molecular hydrogen ions, including H_2^+ and the antimatter equivalent $\bar{H}_2^-$ - in a cryogenic Penning trap [4].

[1] Karr, J.-Ph. et al., Phys. Rev. A **94**, 050501 (2016)
[2] König, C. M. et al., Phys. Rev. Lett., **134**, 163001 (2025)
[3] Karr, J.-Ph. et al., Phys. Rev. A **102**, 052827 (2020)
[4] Myers, E. G., Phys. Rev. A, **98**, 010101 (2018)

Q 63.6 Thu 15:45 N 3

Tungsten Emissivity Modeling and Temperature Diagnostics for the Project 8 Atomic Beam Source — •Brunilda Mucogllava[1], Martin Fertl[1], and Marco Röllig[2] for the KAMATE-Collaboration — [1]Johannes Gutenberg University Mainz — [2]Tritium Laboratory Karlsruhe

To achieve a neutrino-mass sensitivity of 40 meV/c2, the Project 8 experiment aims to employ cyclotron radiation emission spectroscopy to measure the energies of beta-decay electrons from an atomic tritium source. The JGU Mainz atomic test stand uses a Hydrogen Atom Beam Source (HABS) in which molecular hydrogen flows through a 1-mm-diameter tungsten capillary radiatively heated to ~2200 K. The dissociation efficiency of the source depends on the hydrogen flow rate and on the capillary surface temperature. Because the source operates under ultra-high-vacuum conditions, where access is limited and direct-contact sensors risk damaging the capillary, minimally invasive diagnostics, such as optical analysis of its thermal radiation, are preferred. Accurate temperature determination requires reliable knowledge of the tungsten surface emissivity, its evolution over repeated thermal cycles, and the consequent impact on the achievable maximum temperatures. To address these challenges, a dedicated calibration setup was developed at the Tritium Laboratory Karlsruhe to measure tungsten emissivity using a near-infrared spectrometer and a single-wavelength pyrometer. This talk will present new results on tungsten-emissivity modeling and HABS temperature diagnostics, addressing challenges in calibration, temperature stability, and source aging.

Q 63.7 Thu 16:00 N 3

Towards electron and Ca^+ ion cotrapping in a dual-frequency Paul trap — •Vladimir Mikhailovskii[1,2,3], Natalija Sheth[1,2,3], Mohammadreza Nematollahi[1,2,3], Guofeng Qu[4], Michal Hejduk[5], Niklas Vilhelm Lausti[5], K. T. Satyajith[6], Christian Smorra[7], Gunther Werth[3], Neha Yadav[8], Qian Yu[8], Clemens Matthiesen[8], Hartmut Haffner[8], Ferdinand Schmidt-Kaler[3], Hendrik Bekker[1,2,3], and Dmitry Budker[1,2,3,8] — [1]Helmholtz-Institut Mainz, 55128 Mainz, Germany — [2]GSI Helmholtzzentrum fur Schwerionenforschung GmbH, 64291 Darmstadt, Germany — [3]QUANTUM, Institut fur Physik, Johannes Gutenberg-Universitat, 55128, Mainz, Germany — [4]Institute of Nuclear Science and Technology, Sichuan University, 610065, Chengdu, China — [5]Faculty of Mathematics and Physics, Charles University, Prague 8, Czech Republic — [6]Delta Q, MITK, 576217, Moodlakatte, India — [7]Heinrich Heine University Dusseldorf, 40225 Dusseldorf, Germany — [8]Department of Physics, University of California, 94720-7300, Berkeley, USA

Achieving simultaneous cotrapping of oppositely charged particles in the same Paul trap volume is an important milestone in the AntiMatter On a Chip project [1]. In our recent research we studied trapping of either electrons or Ca^+ ions in a dual-frequency field [2]. Here we overview the achieved results, discuss current shortcomings, and propose strategies towards simultaneous trapping of oppositely charged particles, aiming at cotrapping matter and antimatter.

1.N. Leefer, et al. Hyperfine Interact 238, 12 (2017)
2.V. Mikhailovskii, et al. arXiv:2508.16407 (2025)

Q 63.8 Thu 16:15 N 3

Sympathetic cooling and spectroscopy of Ca-Th ion crystal — •Valerii Andriushkov[1,2,3], Ke Zhang[3], Yumiao Wang[3], Darius Fenner[3], Keerthan Subramanian[3], Florian Zacherl[3], Srinivasa Pradeep Arasada[3], Jonas Stricker[1,2,3], Christoph E. Düllmann[1,2,3], Lars von der Wense[3], Ferdinand Schmidt-Kaler[3], and Dmitry Budker[1,2,3,4] — [1]Helmholtz Institute Mainz, Mainz — [2]GSI Helmholtzzentrum für Schwerionenforschung GmbH, Darmstadt — [3]Johannes Gutenberg Universität Mainz, Mainz — [4]Department of Physics, University of California, Berkeley, USA

The TACTICa (Trapping and Cooling of Thorium Ions via Calcium) and NuQuant experiments aim to use ion-trapping techniques to investigate thorium ions for fundamental research, as well as to study ^{229}Th for the development of a nuclear clock. Thorium ions are produced using a laser-ablation ion source and loaded into a linear Paul trap, where they form a mixed-species Coulomb crystal with Ca^+. The thorium ions are efficiently cooled by the co-trapped Ca^+ ions. Our goal is to perform high-precision spectroscopy of thorium ions, which will be achieved with quantum logic spectroscopy. This project is supported by the DFG Project TACTICa (grant agreement no. 495729045) and the BMFTR Quantum Futur II Grant Project NuQuant (FKZ 13N16295A).

Q 64: Poster – Ultra-cold atoms, ions and BEC (joint session A/Q)

Time: Thursday 17:00–19:00 Location: Philo 1. OG

Q 64.1 Thu 17:00 Philo 1. OG

Suppressing crosstalk for Rydberg quantum gates — •Gina Warttmann[1], Florian Meinert[2], Hans Peter Büchler[1], and Sebastian Weber[1] — [1]Institute for Theoretical Physics III and Center for Integrated Quantum Science and Technology, University of Stuttgart, 70550 Stuttgart, Germany — [2]5th Institute for Physics and Center for Integrated Quantum Science and Technology, University of Stuttgart, 70550 Stuttgart, Germany

We present a method to suppress crosstalk from implementing controlled-Z gates via local addressing in neutral atom quantum computers. In these systems, a fraction of the laser light that is applied locally to implement gates typically leaks to other atoms. We analyze the resulting crosstalk in a setup of two gate atoms and one neighboring third atom. We then perturbatively derive a spin-echo-inspired gate protocol that suppresses the leading order of the amplitude error, which dominates the crosstalk. Numerical simulations demonstrate that our gate protocol improves the fidelity by two orders of magnitude across a broad range of experimentally relevant parameters. To further reduce the infidelity, we develop a circuit to cancel remaining phase errors. Our results pave the way for using local addressing for high-fidelity quantum gates on Rydberg-based quantum computers.

Q 64.2 Thu 17:00 Philo 1. OG

Two-component lattice fermions in an optical cavity: competition between pairing orders — •Loïc Philoxene[1], Michele Pini[2], Francesco Piazza[2], and Walter Hofstetter[1] — [1]Goethe-Universität, Institut für Theoretische Physik, 60438 Frankfurt am Main, Germany — [2]Theoretical Physics III, Center for Electronic Correlations and Magnetism, Institute of Physics, University of Augsburg, 86135 Augsburg, Germany

Ultracold atoms dispersively coupled to an optical cavity experience effective long range interactions, leading to a variety of symmetry breaking patterns. On the other hand, spin-1/2 lattice fermions can locally interact via the Hubbard interaction which, when attractive, generally favors pairing. By considering an ultracold gas of two-component fermionic atoms in a static optical square lattice and dispersively coupled to a ring cavity, we analyze the effects of the competition between the cavity-mediated long range interaction and the Hubbard coupling on the pairing instabilities of the Fermi surface. Using a general Hartree-Fock-Bogoliubov mean-field decoupling of the extended Hubbard Hamiltonian describing the low energy physics of the system, we focus on the competition between the Cooper pairing channel and a specific instance of pair density waves that have been shown to be exactly degenerate with the former in a recent study of a similar system with spinless fermions without an underlying lattice. In particular, we show that the Hubbard interaction lifts this degeneracy, and analyze the competition between both types of pairing order.

Q 64.3 Thu 17:00 Philo 1. OG

Optical dipole trapping of mercury — •Sascha Heider, Thorsten Groh, and Simon Stellmer — Universität Bonn, Germany

Mercury, being one of the heaviest laser-coolable elements, is an ideal platform for searches for physics beyond the Standard Model, such as atomic electric dipole moments (EDMs).
We report on the efficient transfer of mercury atoms from a MOT into a high-power (300 W), crossed-beam optical dipole trap paving the way towards degenerate quantum gases of mercury and next-generation atomic EDM searches.

Q 64.4 Thu 17:00 Philo 1. OG

QRydDemo - Architecture for Dynamic Tweezer Arrays — •Ralf Berner[1,2], Christopher Bounds[1,2], Manuel Morgado[1,2], Govind Unnikrishnan[1,2], Achim Scholz[1,2], Jiachen Zhao[1,2], Julia Hickl[1,2], Maximilian Kob[1,2], Sebastian Weber[3,2], Hans-Peter Büchler[3,2], Simone Montangero[4], Christoph Tresp[5], Jürgen Stuhler[5], Tilman Pfau[1,2], and Florian Meinert[1,2] — [1]5th Inst. of Physics, University of Stuttgart — [2]IQST — [3]Inst. for Theoretical Physics III, University of Stuttgart — [4]Inst. for Complex Quantum Systems, University of Ulm — [5]TOPTICA Photonics AG

Within the QRydDemo project, we aim to realize a neutral Rydberg atom quantum computer exploiting the Fine-Structure (FS) qubit in ^{88}Sr atoms trapped in optical tweezers. To this end, we demonstrate a novel type of dynamic tweezer architecture consisting of 20 Acusto-Optical Deflectors (AODs) operating at 592 nm, which are individually driven by up to 64 independent Radio-Frequency (RF) tones, enabling array sizes of up to 500 qubits.
This platform, together with fast image analysis and independent real-time RF-control of the AODs, provides the capability of parallel line sorting with an unprecedented dynamical connectivity, which we can utilize for fast sorting and mid-circuit rearrangement of individual atoms at timescales within the coherence time of the qubits.
We present our work on achieving single atom loading and cooling with a scheme that sequentially addresses red sidebands of the narrow intercombination line in strontium via a frequency chirp. This paves the way towards the generation of large, defect-free arrays of qubits.

Q 64.5 Thu 17:00 Philo 1. OG

Stroboscopic Quantum Sensing in Trapped-Ion Systems — •Frederike Doerr, Florian Hasse, Tobias Spanke, Ulrich Warring, and Tobias Schaetz — Institute of Physics, University of Freiburg, Hermann-Herder-Straße 3, D-79104 Freiburg, Germany

Trapped ions offer exceptional control over quantum motion, enabling precision studies of dynamical and topological phenomena. We present a stroboscopic measurement technique that provides minimally invasive, time-resolved access to an ion's motional state by maintaining coherence among four coupled oscillators: a global microwave reference, a polarization-gradient travelling-wave light field, and the ion's spin and motional states. The method reaches position and momentum sensitivities at the nanometer and zeptonewton-microsecond scale with sub-100 ns time resolution [1], and recent improvements extend its applicability to non-classical motional states. These capabilities open new opportunities for engineered quantum dynamics, including motional N00N states, spin-motion entanglement transfer, and tests of topological amplification effects in parametrically driven, dissipative ion systems [2]. Moreover, resolving extremely small momentum transfers enables probing the weak energy exchange in atom-ion glancing collisions, essential for validating universal quantum-scattering models underpinning quantum-based pressure standards [3]. This framework thus links coherent motional sensing, topological quantum effects, and single-collision physics within a unified trapped-ion platform. [1] RPA 109, 053105 (2024) [2] arXiv:2502.06960 [3] 2020 Metrologia 57 025015

Q 64.6 Thu 17:00 Philo 1. OG

Towards the production of groundstate RbYb — •Arne Kallweit, Céline Castor, and Axel Görlitz — Institut für Experimentalphysik, Heinrich-Heine-Universität Düsseldorf

Ultracold dipolar molecules constitute a promising system for the investigation of topics like ultracold chemistry, novel interactions in quantum gases, precision measurements and quantum information.

Here we report on first experiments in our apparatus for the production of ultracold RbYb molecules. This setup constitutes an improvement of our old apparatus, where the interactions in RbYb and possible routes to molecule production have already been studied extensively [1,2]. In the new setup a major goal is the efficient production of ground state RbYb molecules.

We employ optical tweezers to transport individually cooled samples of Rb and Yb from their separate production chambers to a dedicated science chamber. Here we start to study interspecies interactions of different isotopes by overlapping crossed optical dipole traps. To explore the pathways towards ground state molecules we start with photoassociation spectroscopy near the intercombination line of Yb.

[1] M. Borkowski et al., PRA 88, 052708 (2013)
[2] C. Bruni et al., PRA 94, 022503 (2016)

Q 64.7 Thu 17:00 Philo 1. OG

Studying Rydberg-atom-ion interactions with a high-resolution ion microscope — •Maximilian Futterknecht[1], Jennifer Krauter[1], Óscar Andrey Herrera-Sancho[1], Florian Anschütz[1], Utzuri Högl Vidal[1], Moritz Berngruber[2], Florian Meinert[1], Robert Löw[1], and Tilman Pfau[1] — [1]5th Institute of Physics, University of Stuttgart, Pfaffenwaldring 57, 70569 Stuttgart — [2]Max Planck Institute of Quantum Optics, Hans-Kopfermann-Str. 1, 85748 Garching

Our high-resolution ion microscope enables the spatio-temporally resolved study of interactions between Rydberg atoms and ions in a bulk gas of ultra-cold Rubidium atoms. The apparatus has an achievable lateral resolution of at least 200 nm and allows for three-dimensional imaging. In previous years, the setup was used to study the formation and dynamics of a molecular bond between a single ion and a Rydberg atom, as well as the dynamics of unbound atom-ion states. We plan to extend this endeavor by introducing a second Rydberg state. In an unbound configuration, interactions between two Rydberg states tuned by Förster resonances should be experimentally studied. In a next step, we want to create Rydberg-Rydberg-ion bound states by independently exciting two Rydberg states around a central ion. By state-selective extraction of the three constituents of the formed trimers, we plan to tackle the challenge of distinguishing the three particles on our ion detector and detect triple-coincidences. Spectroscopic measurements and high-resolution imaging will be used to extract information on the electronic and spatial structure of the three-body system.

Q 64.8 Thu 17:00 Philo 1. OG

Stabilizing binary Bose droplets by ions — •Shunsuke Nishimura, Panagiotis Giannakeas, and Jan-Michael Rost — Max Planck Institute for the Physics of Complex Systems, Dresden, Germany

Ultra-dilute liquid droplets formed in binary Bose mixtures constitute weakly interacting yet self-bound quantum fluids, whose quantum-fluctuation-induced stability continues to attract considerable interest. Impurities offer a versatile probe of these systems, and ionic impurities in particular can induce pronounced structural changes through their long-range interactions, as seen in helium nanodroplets. However, their effects in ultra-dilute environments, such as Bose droplets, remain greatly unexplored.

Here we investigate a three-dimensional, spherically symmetric droplet formed by a two-component Bose mixture with contact interactions in the presence of a single ionic impurity. The attractive ion-atom interaction significantly deforms the ground-state density profile and induces a distinct low-lying breathing mode, which remains stable against self-evaporation over a substantially wider range of particle numbers in contrast to the case of the impurity-free droplets. This suggests that ionic impurities offer the possibility to investigate polarons without altering the droplet state even during elementary excitations.

Q 64.9 Thu 17:00 Philo 1. OG

Entanglement-enhanced interferometry using single-atom-resolved Twin-Fock states in 87Rb BECs — •Dominik Köster, Martin Quensen, Mareike Hetzel, and Carsten Klempt — Deutsches Zentrum für Luft- und Raumfahrt e.V. (DLR) Hannover

Atom interferometers are among the most sensitive tools in quantum metrology but are typically limited by the standard quantum limit (SQL). Entangled input states can surpass this bound and approach Heisenberg scaling. We present a metrology-ready 87Rb platform that combines sub-500 ms Bose-Einstein condensate (BEC) production in time-averaged optical potentials with state-resolved, single-atom-resolved detection. We create high-fidelity Twin-Fock states via spin-changing collisions and observe Hong-Ou-Mandel-type atomic interference of up to 10 atoms. Using these states' near-perfect number correlations for heralding, interferometry can be perfomed with large Dicke states for sub-SQL metrology at total atom numbers of 1000 and beyond.

Q 64.10 Thu 17:00 Philo 1. OG

MEMS-Mirror-driven Optical Tweezer for Neutral-Atom Quantum Computing. — •Marcel Keck[1], Jonas Witzenrath[1], Tobias Pätkau[1], Jonas Gutsche[1], Dieter Jaksch[2], Niclas Luick[2], Henning Moritz[2], Thomas Niederprüm[1], Herwig Ott[1], Peter Schmelcher[2], Klaus Sengstock[2], Artur Widera[1], Shanshan Gu-Stoppel[3], Paul Raschdorf[3], and Lena Wysocki[3] — [1]RPTU Kaiserslautern-Landau, 67663 Kaiserslautern, Germany — [2]University of Hamburg, 22761 Hamburg, Germany — [3]Fraunhofer Institute for Silicon Technology, 25524 Itzehoe, Germany

Neutral-atom-based quantum computers are a promising platform for addressing complex optimization problems. These require the ability to deterministically move atoms, not only for initializing a qubit array but also for reaching an all-to-all connectivity. Within the Rymax One project, we investigate mirrors based on Micro-Electro-Mechanical Systems (MEMS) technology to create movable optical tweezers. The development of a new piezo-electric material by the Fraunhofer ISIT that exhibits minimal hysteresis enables the precise positioning of a small mirror surface. In contrast to conventional methods (e.g., AODs), these mirrors introduce no position dependent frequency shift, allow atom movement in all three spatial dimensions, and have a high reflectivity across a broad range of frequencies, including the ultraviolet. To address the entire atomic array of the Rymax One quantum processor, we simulate an optical setup. We characterize different MEMS mirror models and find optimal parameters to ensure quick and stable movement. The oscillations that occur are eliminated.

Q 64.11 Thu 17:00 Philo 1. OG

An Atomtronic Toolbox for Josephson Physics — •Florian Binoth, Kaih T. Mitchell, Erik Bernhart, Jan Gerhardt, Marvin Röhrle, and Herwig Ott — Department of Physics and Research Center OPTIMAS, Rheinland-Pfälzische Technische Universität Kaiserslautern-Landau, 67663 Kaiserslautern, Germany

We present an atomtronic toolbox to study quantum transport phenomena and quantum scattering problems using Bose-Einstein condensates (BECs) in spatially and temporally modulated optical potential landscapes. Our platform generates arbitrary optical potentials with a multi-axis acousto-optical deflector and a digital micromirror device. Additionally, we are developing the implementation of a novel subwavelength dark-state barrier using a pair of resonant Raman beams, with differing transverse modes, projected onto the atoms through an in-vacuum objective lens. The atoms are imaged using a multidirectional absorption imaging system and a scanning electron microscope with high spatial resolution.

This apparatus allows us to investigate atomtronic superconducting Josephson junctions, constructed by introducing a tunnelling barrier into a tube-shaped BEC. With an appropriate combination of AC and DC driving, the current-voltage curve of the device shows discrete Shapiro steps, that have previously been demonstrated in solid-state superconductors and form the Josephson voltage standard. We investigate the microscopic origins of this behaviour and demonstrate that in our quantum gas platform they directly connected to phonon emission and vortex dynamics.

Q 64.12 Thu 17:00 Philo 1. OG

Fano-suppression of losses in scattering resonances of bosonic erbium — •Arfor Houwman[1], Louis Lafforgue[2], Sarah Embacher[1], Manfred Mark[1,2], and Francesca Ferlaino[1,2] — [1]Institut für Quantenoptik und Quanteninformation, Österreichische Akademie der Wissenschaften — [2]Universität Innsbruck, Institut für Experimentalphysik, 6020 Innsbruck, Austria

Lanthanides exhibit remarkable complexity in their scattering properties due to their numerous valence electrons which is reflected in the exceptionally dense Feshbach spectrum in the ground state. Here we explore the situation of bosonic spin mixtures of erbium, adding the additional spin degree to the problem. We observe inter- and intraspin scattering resonances exhibiting a peculiar Fano shape with a pronounced loss minimum, indicating a destructive interference phenomenon. Our multi-channel model captures the essential behaviour and additionally predicts a series of Fano-Feshbach resonances across multiple spin compositions connected to the same molecular state. We observe this series and find good agreement to our model. Our work opens the door for a detailed investigation to study multi-spin strongly-coupled scattering phenomena.

Q 64.13 Thu 17:00 Philo 1. OG

A Cryogenic Surface Trap for experiments with Rydberg ions — •Vinay Shankar[1], Marion Mallweger[1], Simon Schey[1,2], Natalia Kuk[1], Ivo Straka[1], Robin Thomm[1], and Markus Hennrich[1] — [1]Department of Physics, Stockholm University, Stockholm, Sweden — [2]Infineon Technologies Austria AG, Villach, Austria

Trapped Rydberg ions are a unique platform for quantum information processing, metrology and simulations [1,2] as they combine the exceptional control over trapped ions with the tunable, long-range interactions of Rydberg states. Rydberg ions have been used to demonstrate sub-microsecond entangling gates [3]. One of the biggest challenges while working with Rydberg ions is double ionisation due to blackbody radiation, since Rydberg states are close to the ionisation threshold. The operation of the system in a cryogenic environment would reduce this effect significantly, and here we present such an experimental system. The setup hosts a surface ion trap, with separate trapping and experimental zones. Here we present the first measurements with the surface trap with the goal of showcasing Rydberg excitations on such a system. The large polarisability of Rydberg ions makes them highly sensitive to surrounding electric fields and can be utilised as a precise probe for sensing electric fields around the chip.

[1] M. Müller, et al., NJP, 10, 093009 (2008).
[2] F. Schmidt-Kaler, et al., NJP, 13, 075014 (2011).
[3] C. Zhang, et. al., Nature 580, 345 (2020)

Q 64.14 Thu 17:00 Philo 1. OG

Fast single atom spin and number resolved imaging of SU(N) fermions — •Leon Schäfer[1,2], Sophie Häfele[1,2], Thies Plassmann[1,2], Meny Menashes[1,2], and Guillaume Salomon[1,2] — [1]Institute for Quantum Physics, Hamburg University, Luruper Chaussee 149, 22761 Hamburg — [2]The Hamburg Center for Ultrafast Imaging, Hamburg University, Luruper Chaussee 149, 22761 Hamburg

Large local Hilbert spaces are of key interest in quantum science with applications in quantum-computing, -memories, and -simulation of strongly-correlated systems. Multilevel quantum systems such as superconducting circuits, trapped ions, cold molecules and ultracold atoms offer the possibility to realize qudits. Yet, the simultaneous control and detection of multiple quantum states at the single-particle and state level remain a significant challenge. State-of-the-art quantum simulators with single particle and spin detection, such as quantum gas microscopes, also suffer from limited state selectivity and long detection times. We present a rapid imaging technique enabling the simultaneous detection of up to four quantum states encoded in the nuclear spin manifold of ^{87}Sr within $100\,\mu s$. By combining an optical Stern-Gerlach separation protocol with high-fidelity ultrafast imaging in free space we achieve state-resolved detection fidelities in the range of 95-99.3%. This method is compatible with the joint detection of multiple atoms initially confined within the same optical trap. Our technique offers fascinating perspectives for quantum science with alkaline-earth atoms ranging from qudit based quantum computing to quantum gas microscopy of the SU(N) Fermi-Hubbard model.

Q 64.15 Thu 17:00 Philo 1. OG

Towards Autonomous Optical Alignment for NV-Center and SHG Experiments — •Zhen Mi, Tobias Spanke, Frederike Dörr, Jörn Denter, Ulrich Warring, and Tobias Schätz — Physikalisches Institut, Albert-Ludwigs-Universität, Freiburg

We present an automated beam-alignment framework designed for optical experiments requiring long-term stability, in particular NV-center excitation/collection paths and second-harmonic generation (SHG) stages. Stable and reproducible alignment is essential for maintaining photon rates, SHG efficiency, and experimental reliability, yet manual alignment suffers from drift, operator dependence, and time overhead. Our approach combines motorized mirror mounts, in-loop detectors, and gradient-free optimization routines to autonomously explore multi-parameter alignment spaces. We benchmark the system on NV-center fluorescence collection and SHG cavity coupling. The automated routines consistently improve alignment quality, reduce sensitivity to mechanical and thermal drifts, and increase reproducibility across repeated optimization cycles. We further analyze critical aspects such as distinguishing signal drift from noise, managing low-SNR conditions, and maintaining robustness over long measurement sequences. These results lay the groundwork for self-calibrating optical experiments and scalable, low- maintenance optical setups for quantum sensing and nonlinear optics.

Q 64.16 Thu 17:00 Philo 1. OG

Effects of of two-body interactions and quenched disorder on the spectrum and topology of the time-periodically driven Haldane-Falicov-Kimball model — •Souradeep Roy Choudhury[1], Arijit Dutta[1], Tao Qin[2], and Walter Hofstetter[1] — [1]Goethe-Universität, Institut für Theoretische Physik, 60438 Frankfurt am Main, Germany — [2]School of Physics, Anhui University, Hefei, Anhui Province 230601, People's Republic of China

We investigate the time-periodically driven disordered Haldane-Falicov-Kimball model on a honeycomb lattice using real space Floquet dynamical mean field theory. For the clean, noninteracting system, the time-periodic nonequilibrium steady state (NESS) resembles an equilibrium Haldane phase at large driving frequencies but has no effective equilibrium description at intermediate driving frequencies. In presence of the Falicov-Kimball interaction, the pumped charge in a cylinder geometry with a threaded flux does not remain quantized, due to the broadening of the spectral edge modes with increasing interactions till the Mott transition. The rate of energy dissipation into the bath for the clean system shows remarkably different behaviour between the intermediate and large frequency driving regimes. Upon adding onsite static disorder to this system, we find disorder-induced spectral broadening.

Q 64.17 Thu 17:00 Philo 1. OG

Transportable magneto-optical trap of strontium for educational outreach — •Darius Hoyer, Sophia Paul, Johanna Kramer, and Simon Stellmer — Physikalisches Institut, Bonn, Deutschland

The broad linewidth of the 461 nm transition of strontium enables efficient laser cooling and trapping, producing a bright MOT visible to the naked eye. This makes the Sr MOT an ideal, accessible system for demonstrating physics and quantum optics.
We present both the simulation and realization of a portable Sr MOT using permanent magnets for the Zeeman slower and the MOT.

Q 64.18 Thu 17:00 Philo 1. OG

Design of a Dual-Species Atomic Beam Source for High Rubidium and Lithium Flux — •Florian Anschütz[1], Raphael Benz[1], Jennifer Krauter[1], Maximilian Futterknecht[1], Utzuri Ursula Högl Vidal[1], Óscar Andrey Herrera Sancho[1,2], Florian Meinert[1], Robert Löw[1], and Tilman Pfau[1] — [1]5. Physikalisches Institut, Universität Stuttgart, Pfaffenwaldring 57, 70569 Stuttgart, Germany — [2]Escuela de Física, Universidad de Costa Rica, 2060 San Pedro, San José, Costa Rica

Lithium is a promising atomic platform for studying Rydberg molecules in the ultracold regime. For example Rydberg molecules made from Li atoms will allow for resolved rotational spectra, and will allow to study atom ion collisions in the quantum regime. We present the design of a rubidium-lithium dual-species atomic beam source developed for future integration into a high-resolution ion microscope. In order to advance towards dual-species scattering experiments with rubidium and lithium, a bright and well-controlled dual-species atomic beam source is essential. The current source produces overlapping Rb and Li beams with estimated MOT loading rates on the order of 1×10^9 1/s for ^{87}Rb (120 °C) and 3×10^9 1/s for ^{6}Li (400 °C) under dual-species operation. With an improved design, we aim to increase the Rb flux by a factor of $2-3$ while maintaining comparable single-species flux performance. We backup this new design with Monte-Carlo Molecular-Dynamics simulations.

Q 64.19 Thu 17:00 Philo 1. OG

Characterizing Radio Frequency-Induced Pressure Variations in Glass-Cell Vacuum Systems — •Vicente Baca, Alexander Guthmann, Louisa Kienesberger, Felix Lang, David Gopalan, Eleonora Lippi, and Artur Widera — RPTU Kaiserslautern-Landau

In recent years, radio-frequency (RF) magnetic fields have become increasingly important tools in ultracold-atom and quantum-gas experiments. Because many of these experiments rely on glass-cell vacuum chambers, where stable ultra-high vacuum (UHV) is critical, it is essential to verify that the presence of an RF coil (or any source of time-dependent magnetic fields) does not compromise vacuum integrity. In the present work a tunable RF coil was placed near a quartz glass-cell and driven over the MHz regime while monitoring the chamber pressure in real time. We observe frequency dependent pressure variations correlated with the magnitude of the applied RF field. The results contribute to understanding RF-induced perturbations in UHV environments and enhance the design of vacuum systems that incorporate RF fields.

Q 64.20 Thu 17:00 Philo 1. OG

Investigating structural phase transitions in dipolar quantum gases — Christian Gölzhäuser, •Lily Platt, Karthik Chandrashekara, Jianshun Gao, Manon Ballu, Wyatt Kirkby, and Lauriane Chomaz — Physikalisches Institut, Universität Heidelberg, Germany

Dipolar quantum gases have allowed the discovery of novel many-body states (e.g. supersolids), while at the same time providing an outstanding degree of control and tunability. In our new-generation experiment at Heidelberg we aim to study the behaviour of dipolar quantum gases of dysprosium in low dimensions and uniform tailored potentials. Here we report on our investigations on structural phase transitions both from a uniform to a density modulated state by tuning the s-wave scattering length and between a triangular crystal lattice modulation and a stripe-like modulation. We are able to observe the stripe modulation by tilting the orientation of our dipoles in plane through an external field. In both cases of the modulation we are able to observe phase coherence in a small range of scattering lengths below the superfluid to supersolid transition. We aim to study the nature of the different transitions to and within the density modulated regime.

Q 64.21 Thu 17:00 Philo 1. OG

Microwave-Optical Multiphoton Lattice for an Ultracold Atomic Rubidium Quantum Gas — •Patrick Haas, Stefanie Moll, and Martin Weitz — Institut für Angewandte Physik, Bonn, Germany

Quantum simulations of solid state physics theory effects, as well as many applications in quantum information, strongly benefit from recent advances obtained with cold atoms in optical lattices. Here we report on progress in the development of a state-selective optical lattice for alkali atoms despite the usage of extremely far detuned trapping light fields. For this, we employ a doubly resonant lattice scheme that combines optical and microwave transitions. We present both the basic working scheme as well as results of a proof-of-principle experiment demonstrating the resulting spatially varying trapping potential for cold rubidium atoms. Prospects of this work include fault-tolerant quantum computation as well as measurement-based quantum information processing.

Q 64.22 Thu 17:00 Philo 1. OG

Towards continuous superradiance in Strontium-88 — •Ying Cui, Luuk Michels, Elisa Wenzel, Benedikt Heizenreder, Ananya Sitaram, and Florian Schreck — University of Amsterdam

Superradiance is a collective light-matter phenomenon with the potential of significantly enhancing the short-term stability of optical clocks. While pulsed superradiance has already been demonstrated, we envision a steady supply of ultracold atoms actively transported through the lasing region to achieve continuous operation. Here we present two sub-projects towards continuous superradiance on the millihertz line of Strontium-88. We plan to employ a bow-tie cavity to form a moving optical lattice that acts as a conveyor belt for transporting atoms from a reservoir into the emission region. The first objective is to couple and lock the cavity to this lattice light and to implement a probing setup that targets the 689 nm 1S0-3P1 transition in Strontium. A further key requirement is the controlled, yet incoherent preparation of atoms in the upper lasing state, preventing any imposed phase relation between the pump beams and the emitted superradiant field. To this end, we aim to develop and implement a multi-level pumping scheme, supported by a frequency and intensity stabilized repumping system integrated into the experiment.

Q 64.23 Thu 17:00 Philo 1. OG

Tools for quantum simulation with circular Rydberg states of a divalent atom — •Aaron Götzelmann, Einius Pultinevicius, Armin Humic, Marius Thomas, Christian Hölzl, Fabian Thielemann, and Florian Meinert — 5. Physikalisches Institut, Universität Stuttgart, Stuttgart, Germany

In our quantum experiment we aim to realize a quantum simulator with circular Rydberg states (CRS) of strontium. Compared to low-ℓ Rydberg states, CRS offer orders-of-magnitude longer lifetime, which allows for overcoming fundamental limitations for system coherence. The maximally allowed angular momentum and magnetic quantum numbers provided by the CRS yield limited decay channels, that can be suppressed by decreasing the mode-density in the black-body regime leading to extreme lifetimes [1]. To this end we use the Purcell-effect provided by a capacitor structure around the atoms [2].

As a divalent alkaline-earth Rydberg atom, strontium offers several advantages over monovalent elements because of the optically active ionic core. This is specifically true for CRS, which allows for coherent operation of the Sr^+ ion with its level structure. This gives rise to various tools for our quantum simulator, such as trapping, cooling, side selective addressing [3], and fluorescence imaging of Rydberg atoms. In my contribution, I will show our endeavours on the optical detection of a CRS.

[1] Pultinevicius et al., arXiv:2510.27471 (2025)
[2] Hölzl et al., Phys. Rev. X 14, 021024 (2024)
[3] Wirth et al., Phys. Rev. Lett. 133, 123403 (2024)

Q 64.24 Thu 17:00 Philo 1. OG

Fast SLM holography for arbitrary atom transport in neutral atom QPUs. — •Maximilian Kob[1,2], Christopher Bounds[1,2], Manuel Morgado[1,2], Govind Unnikrishnan[1,2], Ralf Berner[1,2], Achim Scholz[1,2], Jiachen Zhao[1,2], Julia Hickl[1,2], Tilman Pfau[1,2], and Florian Meinert[1,2] — [1]5th Inst. of Physics, University of Stuttgart — [2]IQST

We report on progress towards a fully dynamical optical tweezer platform employing fast, phase-only spatial light modulators (SLMs) within the QRydDemo demonstrator. Due to intensity flickering along sequences of Gerchberg-Saxton (GS)-based holograms, smooth transitions between frames are generated using the Linear Phase Interpolation (LPI) method [1]. This mitigates losses during transport through light-field phase control. Our control software has been adapted to include a GPU-accelerated implementation of the LPI and to support arbitrary two-dimensional trajectories. The neutral-atom platform based on optical tweezers offers the possibility of 3-dimensional (3D) atom assembly. We compare several methods for generating static 3D holograms and evaluate their suitability for atom transport, supported by optical and dynamical simulations. To enable fully 3D atom transport for sorting and shuttling, we further present an evaluation of the performance of different techniques for generating 3D holograms near kHz timescales.

[1] I. H. A. Knottnerus et. al. SciPost Phys. 19, 118 (2025)

Q 64.25 Thu 17:00 Philo 1. OG

Design of a new accordion optical lattice for a quantum gas microscope — •Lennart Hoenen[1], Carlos Gas[2], Andreas Meyer[2], Lauriane Chomaz[1], and Leticia Tarruell[2] — [1]Physikalisches Institut Heidelberg, Im Neuenheimer Feld 226, 69120 Heidelberg, Germany — [2]ICFO - The institute of photonic sciences, Mediterranean Technology Park, Avinguda Carl Friedrich Gauss, 3, 08860 Castelldefels, Barcelona, Spain

In this poster, the design of a dynamically tunable accordion optical lattice is presented, which was developed for the Strontium quantum gas microscope experiment in the Tarruell group. The design is expected to enable dynamic tuning of the vertical confinement from 9kHz to 25kHz, corresponding to a change in lattice spacing from 1.9um to 5.1um, while remaining below 80Hz in the horizontal direction. The functionality of the accordion lattice is demonstrated in a dedicated test setup, validating its performance and tunability.

This technical advancement opens new possibilities for exploring strongly correlated SU(N) symmetric systems in tailored 2D geometries under a quantum gas microscope

Q 64.26 Thu 17:00 Philo 1. OG

Morphological false vacuum decay in dipolar supersolids — •Wyatt Kirkby[1,2], Thomas Gasenzer[2], and Lauriane Chomaz[1] — [1]Physikalisches Institut, Universität Heidelberg, Heidelberg, Germany — [2]Kirchhoff-Institut für Physik, Universität Heidelberg, Heidelberg, Germany

We theoretically study false vacuum decay between two morphologically distinct phases of a two-dimensional atomic dipolar supersolid via bubble nucleation, within an extended Gross-Pitaevskii framework including quantum fluctuations. We model the decay rate by deriving an effective action and instanton bounce solution describing the transition between honeycomb and stripe supersolid orders. Numerical simuations of stochastic decay events are then compared against this field-theoretic approach. We also compare bubble growth velocities with the longitudinal and transverse sound speeds of the competing supersolid orders.

Q 64.27 Thu 17:00 Philo 1. OG

Rymax one: A neutral atom quantum processor to solve optimization problems — •Silvia Ferrante[1], Jonas Witzenrath[2], Tobias Ebert[1], Kapil Goswami[1], Hendrik Koser[1], Tobias Pätkau[2], Benjamin Abeln[1], Hauke Biss[1], Giovanni de Vecchi[1], Jonas Gutsche[2], Nader Mostaan[1], Rick Mukherjee[3], Suthep Pomjaksilp[1], Niclas Luick[1], Thomas Niederprüm[2], Dieter Jaksch[1], Henning Moritz[1], Herwig Ott[2], Peter Schmelcher[1], Klaus Sengstock[1], and Artur Widera[2] — [1]University of Hamburg, 22761 Hamburg, Germany — [2]RPTU Kaiserslautern-Landau, 67663 Kaiserslautern, Germany — [3]University of Tennessee, TN 37996 Knoxville, USA

From the optimisation of supply chains to efficient vehicle routing - computationally hard problems are deeply embedded into modern society. Finding solutions to these problems via classical means still requires substantial computational effort. Quantum processors, on the contrary, promise a significant advantage in solving them.

Here we present Rymax one, a quantum processor based on neutral Ytterbium designed to explore the potential of quantum computing for real world applications. The level structure of Yb naturally provides qubits with long coherence times as well as high-fidelity gate operations. These features allow us to realise a scalable platform to test the performance of novel quantum algorithms tailored to tackle real-world problems.

Q 64.28 Thu 17:00 Philo 1. OG

Stabilizing the repulsive Bose polaron — •René Henke, Cesar R. Cabrera, and Henning Moritz — Institut für Quantenphysik, Universität Hamburg

Mobile impurities interacting with a quantum medium form quasiparticles known as polarons, a central concept in many-body physics. While the quantum impurity problem has been extensively studied with ultracold atomic gases, repulsive polarons in the strongly correlated regime have remained elusive. Typically, impurity atoms bind to molecules or rapidly decay into deeper-lying states before they can acquire an appreciable dressing cloud. Here, we report on the realization of polarons in a strongly repulsive quasi-two-dimensional quantum gas. Using a superfluid of ^{6}Li dimers, we introduce impurities by promoting a small fraction of the dimers into higher levels of the transverse confining potential. These synthetic-spin polarons give access to the strongly repulsive regime where common decay channels are suppressed. We extract key polaron properties—the energy, quasiparticle residue, and effective mass—using trap modulation and Bragg spectroscopy. Our measurements are well captured by a microscopic T-matrix approach and quantum Monte Carlo simulations, revealing deviations from mean-field predictions. In particular, we measure a significant enhancement of the polaron mass, with values exceeding twice the free dimer mass. Our demonstration of a stable repulsive Bose polaron establishes a platform for studying impurity physics in low-dimensional and strongly correlated systems.

Q 64.29 Thu 17:00 Philo 1. OG

Temperature-dependent extended Gross-Pitaevskii treatment for dipolar quantum gases — •Julian Kusch, Wyatt Kirkby, and Lauriane Chomaz — Physikalisches Institut, Universität Heidelberg

We investigate the theoretical effects of finite temperature on dipolar quantum gases. The extended Gross-Pitaevskii equation (eGPE) serves as the general framework, including isotropic contact interactions, anisotropic long-range dipole interactions and beyond-mean-field effects. By extending the eGPE to include a term based on Bogoliubov theory, we describe the influence of finite temperatures and study the impact on the phase diagram and real-time evolution. We also compare our results directly with experimental observations from the Heidelberg Dysprosium lab.

Q 64.30 Thu 17:00 Philo 1. OG

Progress toward a Lithium-based quantum gas microscope — •Shaurya Bhave, Ruijia Li, Binayak Rout, and Timon Hilker — University of Strathclyde, Glasgow, United Kingdom

Neutral atoms have taken ground as a compelling platform, for both analog and digital quantum simulation. They bring several advantages such as long lifetimes, naturally identical qubits, and inherent scalability. Optical lattice based tunneling gates, are expected to enhance the toolkit of simulation experiments to realise hybrid quantum processors. This approach combines the power of Hubbard simulations, with the programmability of quantum gates, utilising the inherent fermion exchange statistics of cold atoms. Here we present our progress towards a new lithium quantum gas microscope. Our goal is to gain full control over the motion of the atoms, by employing an optical superlattice and single site addressing to create quantum gates. We aim for fast cycle times and robust preparation of deeply degenerate gases using a single-chamber design with a high-power optical lattice directly loaded from a MOT.

Q 64.31 Thu 17:00 Philo 1. OG

Long-lived giant circular Rydberg states at room temperature for quantum simulation — •Einius Pultinevicius, Aaron Götzelmann, Armin Humic, Marius Thomas, Fabian Thielemann, Christian Hölzl, and Florian Meinert — 5. Physikalisches Institut, Universität Stuttgart

Highly excited Rydberg atoms feature extreme properties, making them valuable for many applications ranging from sensing to the use in quantum computing and simulation. Commonly used low-ℓ, optically accessible Rydberg states have a limited lifetime which imposes a fundamental restriction on their coherence times. In our experiment, we overcome this limitation by transferring the Rydberg electron to a circular Rydberg state (CRS) with maximally allowed orbital momentum. The use of a transparent capacitor with indium-tin-oxide-coated glass plates reduces the mode-density of resonant black-body photons, further increasing the lifetime while preserving optical access.

Here, we characterize this effect over a wide range of n from 79 up to 101, enabled by successive coherent population transfer between close-by CRS. The measured decay dynamics indicate additional resonant features involving additional decay paths, which are explained by taking into account the full electrode structure around the atom. We demonstrate lifetimes reaching 10 ms at room-temperature and a trapping time of more than 100 ms, paving the way for experiments with Rydberg atoms on unprecedented timescales.

Q 64.32 Thu 17:00 Philo 1. OG

Towards Lithium Bose-Fermi-mixtures in a compact experimental apparatus — •Jonathan Bracker, Martin Guillot, and Christof Weitenberg — Technische Universität Dortmund

We present the design of a versatile lithium quantum gas machine with a 2D/3D MOT setup and high-resolution access with an NA of 0.5. A matter-wave microscope using optical traps allows magnifying the density by a factor of 35. It also enables the realisation of a phase microscope, mapping phase fluctuations to density fluctuations for a BEC in a triangular optical lattice. Upon the reassembly of the machine after relocation, we are currently implementing an upgrade to allow for the preparation of Bose-Fermi mixtures of Li7 and Li6. We present the laser system that provides all the necessary frequencies for simultaneous sub-Doppler laser cooling as well as future plans to use the mixture for studying various scenarios of driven-dissipative systems. In particular, we will use the Li6 cloud as a bath to absorb heating of a Li7 system upon manipulation with moderately near-resonant light.

Q 64.33 Thu 17:00 Philo 1. OG

Optimizing pulsed resolved sideband cooling outside the Lamb–Dicke regime — •Elwin A. Dijck, Sebastian Davidson, Ruben B. Henninger, Shreya Rao Kodancha, Devanarayanan Rajeeb Kumar, Stepan Kokh, Vera M. Schäfer, Thomas Pfeifer, and José R. Crespo-López Urrutia — Max-Planck-Institut für Kernphysik, Heidelberg

Cooling ions to the motional ground state of their harmonic trapping potential minimizes Doppler shifts and enables techniques like quantum logic spectroscopy. Ion motion modulating a narrow transition produces resolved sidebands that allow changing the motional state in controlled steps beyond the Doppler limit. In the Lamb–Dicke regime, the modulation is small: repeated excitation of the first-order red sideband and repumping successively lowers the phonon number to zero.

Limited trap depth may prevent reaching this regime and presents challenges in sideband cooling: the Doppler limit now corresponds to a larger initial phonon number, and absorption and emission during repumping cause significant heating. However, the larger modulation index also produces higher order sidebands in the spectrum, allowing removal of more than one phonon per step.

Simulating the probability distribution over Fock states for one and two-ion crystals during the cooling process, we investigate optimized pulse sequences for different combinations of Lamb–Dicke factors and ion species, considering in particular mixed-species crystals comprising a Be^+ ion and a highly charged ion.

Q 64.34 Thu 17:00 Philo 1. OG

Confinement-induced stabilization of a resonantly interacting ultracold Bose-Fermi mixture — •Tommaso Vedovello, D Digvijay, Premjith Thekkeppatt, Klaasjan van Druten, and Florian Schreck — Van der Waals-Zeeman Institute, University of Amsterdam, Netherlands

Alkaline–alkaline-earth dimers exhibit both an electric and a magnetic dipole moment and they are a promising platform for studying quantum many-body effects, precision measurements, quantum computation and quantum chemistry. In our experiment [1] we aim to produce such molecules starting from an ultracold Bose-Fermi 87Rb-87Sr mixture. The ultracold scattering properties of this mixture have been previously determined in our group [2,3], and the mixture was found to be resonantly interacting, with losses attributed to 3-body recombination [4]. We observed the suppression of these losses by confining the gas to lower dimension in a 1D optical lattice . In such a quasi-2D regime, the resonantly interacting mixture has a long lifetime, up to hundreds of milliseconds, which is an excellent starting point for pursuing molecule formation, for instance through confinement-induced resonance [5]. Our immediate next goal is to confirm this through a two-photon scheme (STIRAP). This is the next step towards creating the first ultracold open-shell heteronuclear ground-state molecules.

[1] P. Thekkepatt, et al., PRL 135, 193001 (2025) [2] A. Ciamei, et al., Phys.Chem.Chem.Phys 20, 26221 (2018) [3] V. Barbé et al., Nat. Phys.14, 881 (2018) [4] P.O. Fedichev, et al., PRL 77, 2921 (1996) [5] L. Oghittu et al., PRA 112, 043313 (2025)

Q 64.35 Thu 17:00 Philo 1. OG

Bayesian Optimization of Measurement Protocols for the Thermometry of Ultracold Gases — •Luca Leon Granert, Julian Fess, Sabrina Burgardt, Silvia Hiebel, and Artur Widera — Department of Physics, RPTU University Kaiserslautern-Landau, 67663 Kaiserslautern, Germany

Precise thermometry in ultracold gases is essential for exploring quantum many-body phenomena. Established methods, such as time-of-flight thermometry, lose precision in regimes with weak signals and often destroy the sample. Quantum probes provide a non-destructive approach by encoding environmental information into internal states with minimal disturbance to the system. In this work, spin-based quantum thermometers are realized by immersing individual Cs atoms into an ultracold Rb bath. Inelastic spin-exchange processes between probe and bath transfer motional and thermal information onto the internal spin states. The information gained per inelastic event increases when nonequilibrium spin dynamics are exploited. The optimal parameters for this process depend on the temperature being estimated, making this system well-suited for Bayesian estimation strategies. Three measurement protocols are investigated: an unoptimized, an a priori optimized, and an adaptively optimized version. Their performance is evaluated based on their convergence behavior and achievable estimation accuracy. The a priori optimized protocol shows the best performance in this comparison. These results show that nonequilibrium probe dynamics can enhance quantum thermometry, supporting efficient and precise temperature estimation in ultracold environments.

Q 64.36 Thu 17:00 Philo 1. OG

Realizing and probing programmable 2D optical lattices with flexible geometries and connectivity — •Sheng-Hung Wang[1,2], Kritsana Srakaew[1,2], David Wei[1,2], Daniel Adler[1,2], Suchita Agrawal[1,2], David Gröters[1,2], Pascal Weckesser[1,2], Immanuel Bloch[1,2,3], and Johannes Zeiher[1,2,3] — [1]Max-Planck-Institut für Quantenoptik, Garching, Germany — [2]Munich Center for Quantum Science and Technology, Munich, Germany — [3]Fakultät für Physik, Ludwig-Maximilians-Universität, Munich, Germany

Optical lattices are a versatile platform for studying complex and highly correlated quantum many-body systems. For most experiments, the layout of the confining lattice beams restricts the accessible lattice geometries and the underlying physics. We recently overcame this challenge by introducing a passively phase-stable tunable lattice, which offers programmable cell connectivity and flexible geometries, including square, triangular, Lieb, and Kagome lattices [1]. In this poster, we present our tunable lattice geometries and demonstrate out-of-equilibrium quantum walks for different settings. Furthermore, we introduce a new upgrade that will enable mid-sequence tunabilty, allowing for doublon and spin-resolved imaging. In addition, we discuss cooling techniques that will boost the overall preparation time for ultracold atoms in optical lattices.

[1] Wei et al. Physical Review X 13.2 (2023): 021042.

Q 64.37 Thu 17:00 Philo 1. OG

Spin-resolved microscopy of an SU(N) Fermi-Hubbard system — •Leonardo Bezzo[1], Carlos Gas-Ferrer[1], Sandra Buob[1], Antonio Rubio-Abadal[1], and Leticia Tarruell[1,2] — [1]ICFO, Castelldefels (Barcelona), Spain — [2]ICREA, Barcelona, Spain

Quantum-gas microscopes have provided direct access to the phases of the Fermi-Hubbard model. For SU(2) systems, they have brought microscopic insight into the complex competition between interactions, quantum magnetism, and doping. Alkaline-earth(-like) fermions extend this spin-1/2 paradigm by giving access to SU(N) Fermi-Hubbard models, with rich phase diagrams to be unveiled. Despite its fundamental interest, a microscopic exploration of SU(N) quantum systems has remained elusive. We report the realization of a quantum-gas microscope for fermionic ^{87}Sr. Our fluorescence imaging scheme, based on cooling and detection on the narrow intercombination line at 689 nm, enables spin-resolved single-atom detection. By combining it with an optical pumping protocol, we are able to detect the 10 spin states occupation in a single experimental run, a crucial capability for probing site-resolved magnetic correlations. Moreover, we characterize the fundamental inelastic photon scattering processes that limit the site-resolved fidelity of our imaging protocol, and demonstrate an extension of our method that allows us to reach fidelities > 96% for systems up to SU(8). These results establish ^{87}Sr quantum-gas microscopy as a powerful approach to study exotic magnetism in the SU(N) Fermi-Hubbard model, and provide a new detection tool with potential applications to quantum simulation, computation, and metrology.

Q 64.38 Thu 17:00 Philo 1. OG

Enhanced Atom Capture via Multi-Frequency Magneto-Optical Trapping — •Benjamin Hopton, Nathan Cooper, and Lucia Hackermuller — School of Physics and Astronomy, University of Nottingham, UK

Cold atom traps have a wide range of applications, from sensing—in devices such as magnetometers and gravimeters—to tests of fundamental physics. Increasing the size of these atom traps increases the sensitivity of such experiments; additionally, increasing the load rate of these traps inevitably increases the bandwidth of any device using these traps. We deliver an experiment showing that using multi-frequency cooling light in a Rb-87 magneto-optical trap (MOT) doubles the total number of atoms captured (capturing up to 1.3×10^{10} atoms) and further improves the load rate of the trap three-fold (up to $1.2 \times 10^{11}\,\mathrm{s}^{-1}$) compared to a traditional single-frequency MOT using the same apparatus. The use of multiple frequencies, each separated on the order of the natural linewidth of the atomic transition in question, allows a larger range of Doppler shifts—or higher velocity classes—to be available for excitation from the laser; this allows atoms to remain on resonant with the laser as it is cooled, increasing the capture velocity of a MOT for the same given size. We aim to continue optimising the setup for greater increase in both loading rate and steady-state atom number, in addition to implementing high atom number interferometric techniques, of which we have simulated.

Q 64.39 Thu 17:00 Philo 1. OG

Towards a UV single-site addressing system for a hybrid fermionic quantum processor — •Ino Ahrens[1,2], Francesco Testi[1,4], Luca Muscarella[1,3], Robin Groth[1,3], Andreas von Haaren[1,3], Liyang Qiu[1,3], Titus Franz[1,3], Philipp Preiss[1,3], and Immanuel Bloch[1,3,4] — [1]Max-Planck Institute of Quantum Optics — [2]Technical University of Munich — [3]Munich Center for Quantum Science and Technology — [4]Ludwig Maximilian University Munich

FermiQP is a demonstrator for a fermionic quantum processor utilizing ultracold fermions in optical lattices. Operating in analog mode, the system facilitates precision studies of the two-dimensional Fermi-Hubbard model. In its digital mode, it aims to implement a universal gate set on the spin degree of freedom, enabling advanced state engineering and local basis transformations. We present a single-atom addressing scheme for coherently manipulating the internal states of individual Lithium-6 atoms in an optical lattice. The scheme employs differential light shifts near a UV transition at 323 nm, maximizing atomic coherence while minimizing cross-talk to neighboring lattice sites. We report on the characterization of our high numerical aperture UV microscope objective and the current status of the implementation of our single-site addressing setup, which incorporates two polarization independent AODs.

Q 64.40 Thu 17:00 Philo 1. OG

Photonic bandgaps and normal mode splitting in lattices interacting with optical cavities — Philippe Wilhelm Courteille[1], •Dalila Rivero[1], Gustavo Henrique de França[1], Claudio Alves Pessoa Junior[1], Ana Cipris[1], Mayerlin Nuñez Portela[2], Raul Teixeira[3], and Sebastian Slama[4] — [1]Instituto de Física de São Carlos, Universidade de São Paulo, São Carlos, São Paulo 13566-970, Brazil — [2]Laboratorio de Óptica Cuántica, Universidad de los Andes, A.A. 4976, Bogotá D.C., Colombia — [3]Departamento de Física, Universidade Federal de São Carlos, São Carlos, São Paulo 13565-905, Brazil — [4]Center for Quantum Sciences and Physikalisches Institut, Eberhard-Karls Universität Tübingen, 72076 Tübingen, Germany

At low optical density, the atom-cavity system is described by the open Dicke model, where collective coupling strength determines the width of normal mode splitting. We apply this to ordered clouds in linear and ring cavities and demonstrate its use in witnessing Wannier-Bloch oscillations. At high optical density, the atomic distribution reshapes the cavity mode, requiring a transfer matrix model. For a periodic atomic lattice, this reveals competing photonic band gaps and normal mode splitting. We discuss the limitations of both models and pathways to more generalized theories.

Q 64.41 Thu 17:00 Philo 1. OG

A New-Generation Rydberg Atom Quantum Simulator — •Lukas Klein, Bastien Gély, Mu Qiao, Romain Martin, Thierry Lahaye, and Antoine Browaeys — University Paris-Saclay, Institut Optique Graduate School

We are building a new-generation Rydberg atom array setup for quantum simulations that will replace the existing setup developed at Institut d'Optique over the last decade. With this platform, single atoms are arranged in arbitrary geometries by optical tweezers. Using Rydberg states, it is then possible to implement many-body spin Hamiltonians [1]. Most recent works include the XY spin model [2] and the t-J spin model [3].

I will present the construction of the new-generation setup, that improves several important features of the machine. One major upgrade are the focusing optics, which used to be aspheric lenses on the old setup and are now high NA (0.57) microscope objectives. We are therefore able to generate larger arrays of single Rb-87 atoms.

I will further present some experimental results demonstrating our control over the atoms, such as state preparation and manipulation in ground and Rydberg states. Furthermore, we refined the technique of grey molasses used for cooling and enhanced loading - reaching filling fractions of more than 85%.

References

[1] A. Browaeys and T. Lahaye, *Nature Physics* 16, 132 (2020).
[2] G. Emperauger *et al.*, *Phys. Rev. X* 15, 031021 (2025).
[3] M. Qiao *et al.*, *Nature* 644, 889-895 (2025).

Q 64.42 Thu 17:00 Philo 1. OG

Towards Bose-Einstein condensation of strongly dipolar mixtures of dysprosium atoms — Lennard Reihs, Marian Duerbeck, Johannes Seifert, Bhalchandra Choudhari, Juan Pablo Marulanda, Nelson Werum, Marco De Pas, Gerard Meijer, and •Giacomo Valtolina — Fritz-Haber-Institut der Max-Planck-Gesellschaft, Faradayweg 4-6, 14195 Berlin, Germany

Quantum gases of magnetic atoms, such as dysprosium (Dy), can provide access to a wide range of exotic many-body physics. Prominently, this included the recent realization of the long-sought-after supersolid phase. A richer landscape of supersolid phases has been theoretically predicted for mixtures of these magnetic atoms. We report on our efforts to create stable mixtures of Dy. We show a broadly applicable frequency-modulation scheme for simultaneous slowing and trapping of different isotopes of Dy and discuss progress toward producing mixtures of strongly dipolar Bose-Einstein condensates.

Q 65: Poster – Ultra-cold plasmas and Rydberg systems (joint session A/Q)

Time: Thursday 17:00–19:00 Location: Philo 1. OG

Q 65.1 Thu 17:00 Philo 1. OG

Cryogenic Strontium Quantum Processor — •Roberto Franco, Xintong Su, Valerio Amico, Jonas Drotleff, and Christian Gross — University of Tübingen

In our project we aim at the unification of the optical tweezer technology with cryogenic technology at 4K, exploiting the stability of nuclear spin qubits encoded in fermionic strontium. This will result in record-long coherence and lifetimes of the atoms in the optical tweezer array. We report our efforts on the architecture to perform single qubit gates and the plans for adding two-qubit gates in the experiment.

Q 65.2 Thu 17:00 Philo 1. OG

Hilbert space fragmentation in driven-dephasing Rydberg atom array — •tianyi yan, chunhei leung, and weibin li — School of Physics and Astronomy and Centre for the Mathematics and Theoretical Physics of Quantum Non-equilibrium Systems, University of Nottingham, Nottingham NG7 2RD, United Kingdom

We investigate the onset and mechanism of Hilbert space fragmentation (HSF) in a chain of strongly interacting Rydberg atoms subject to local dephasing. It is found that the emergence of multiple long-lived metastable states is fundamentally tied to HSF of the driven-dephasing Rydberg atom system. We demonstrate that the manifesting HSF is captured by a dephasing PXP model that supports multiple degenerate zero modes. These modes form disconnected, block-diagonal subspaces of maximally mixed states, which consist of many-body spin states sharing the same symmetry. A key result is the identification of the underlying symmetry in the HSF, where conserved quantities in each subspace are defined by the consecutive double excitation addressing operator. Moreover, we show explicitly that the number of the fragmented Hilbert space grows exponentially with the chain length, following a modified Fibonacci sequence. Our work provides insights into many-body dynamics under dynamical constraints and opens avenues for controlling and manipulating HSF in Rydberg atom systems.

Q 65.3 Thu 17:00 Philo 1. OG

Construction of a versatile platform for Rydberg atom experiments — •Aaron Thielmann, Dominik Issler, Erik Bernhart, Sven Schmidt, Thomas Niederprüm, and Herwig Ott — Department of Physics and research center OPTIMAS, RPTU Kaiserslautern-Landau

In recent years, atomic arrays emerged as a ground-breaking platform in quantum physics. These setups feature single-atom control and offer large flexibility to study quantum information processing and many-body physics in different geometric configurations.

We present a new experimental setup utilizing a stainless steel chamber and in vacuum electrodes, allowing to produce arrays of single atoms or small samples, while having as much control over sorrounding parameters as possible. We use holographically generated traps from an SLM at a wavelength of 1064nm, which are projected together with additional addressing beams through a high resolution objective into the vacuum chamber. This opens the possibility to site-selectively excite and deexcite the atoms using multiple two- and three-photon transitions, thus enabling the investigation of transport with controlled dissipation in arbitrarily arranged arrays of Rubidium atoms. Additional features include electric and magnetic field control in combination with an ion detector as well as the ability for global application of microwave and optical fields.

Q 65.4 Thu 17:00 Philo 1. OG

Collectively Enhanced Detection — •Lew Schöne, Amar Bellahsene, Swayangdipta Bera, Clément Gradziel, Maximilian Müllenbach, Shuzhe Yang, Tom Bienaimé, and Shannon Whitlock — Centre Européen de Sciences Quantiques, Institut de Science et d'Ingénierie Supramoléculaire (UMR 7006), Strasbourg, France

Arrays of single atoms in optical tweezers are a strong contestant in the race for quantum computing and simulation platforms (1). Besides their strengths - scalability, environmental isolation and adaptability - the system still lags speed when it comes to qubit manipulation and readout. This project aims to implements a new fast detection scheme to enable measurements on the microsecond timescale.

In the group of Prof. Whitlock in Strasbourg we have experience with arrays of atomic ensembles in microtraps (2). We now want to combine ensembles with single atoms to realize collectively enhanced detection using Rydberg electromagnetically induced transparency (3) to detect the state of a single atomic qubit. The big challenges of this measurement scheme are the preparation of the atomic ensembles and the single atom in neighboring tweezers, as well as an optimized interaction and readout sequence. Implemented on a potassium quantum gas machine, this new detection method will enable fast and state sensitive measurements.

(1) M. Morgado and S. Whitlock, AVS Quantum Science 3, no. 2 (2021)

(2) Y. Wang et al., Npj Quantum Information 6, no. 1 (2020)

(3) W. Xu et al., Physical Review Letters 127, no. 5 (2021)

Q 65.5 Thu 17:00 Philo 1. OG

Study of Rydberg states in ultracold ytterbium — •Nele Koch, Alexander Miethke, Jellina Nuha, and Axel Görlitz — Heinrich-Heine-Universität, Institut für Experimentalphysik, Düsseldorf, Germany

In recent years Rydberg atoms with their special features, like dipole-dipole interaction or van-der-Waals blockade, have become more and more important for quantum optics. Particularly ultracold Rydberg atoms are of great interest for the investigation of long range interaction.

A special feature of ytterbium is that due to its two valence electrons atoms in Rydberg states can be easily manipulated and imaged using optical fields. A first step towards studies of ultracold ytterbium is to gain precise knowledge on the Rydberg states.

Here we present the study of the Rydberg states of ultracold ytterbium. Using a Micro-Channel-Plate to detect the Rydberg atoms it is possible to measure lifetimes and hyperfine structures of several states (n=35-90). In addition we could measure the energy and polarizability of s, p and d states in the region of high principal quantum numbers n (n=70-90). Using a second stage trap we are able to cool the atoms down to several micro K to reduce their distances and investigate interactions.

Q 65.6 Thu 17:00 Philo 1. OG

Towards the simulation of 2D lattice gauge theories in decorated Rydberg tweezer arrays — •Roxana Wedowski[1], Ana Pérez Barrera[1], Quentin Redon[1], Julia Bergmann[1,2], Alessio Celi[1,2], and Leticia Tarruell[1,3] — [1]ICFO - Institut de Ciencies Fotoniques, Castelldefels (Barcelona), Spain — [2]Universitat Autònoma de Barcelona (UAB), Barcelona, Spain — [3]ICREA, Institució Catalana de Recerca i Estudis Avançats, Barcelona, Spain

Solving strongly coupled gauge theories in more than one dimension is of fundamental importance in several areas of physics, ranging from high-energy to condensed matter physics. On a lattice, gauge invariance and gauge-invariant interactions involve challenging multi-body interactions to realize in quantum simulators. Engineering generalized blockade interactions in decorated arrays of Rydberg atoms has been proposed as a solution to this challenge. In my poster, I will present our current construction of the strontium Rydberg tweezer platform at ICFO based on this approach. This approach should enable us to realize plaquette interactions and engineer the Rokhsar-Kivelson Hamiltonian with minimal experimental complexity. Specifically, I will discuss our latest progress on the construction of the experimental platform.

Q 65.7 Thu 17:00 Philo 1. OG

Effect of small interaction terms in a time-reversal protocol for a Rydberg Quantum Simulator — •Varad Dhodapkar[1], Maharshi Pran Bora[2], Eduard Braun[3], Meny Menashes[4], Matthias Lotze[5], Gerhard Zuern[6], and Matthias Weidemueller[7] — [1]Physikalisches Institut, Im Neuenheimer Feld 226, 69120 Heidelberg — [2]Physikalisches Institut, Im Neuenheimer Feld 226, 69120 Heidelberg — [3]Physikalisches Institut, Im Neuenheimer Feld 226, 69120 Heidelberg — [4]Physikalisches Institut, Im Neuenheimer Feld 226, 69120 Heidelberg — [5]Physikalisches Institut, Im Neuenheimer Feld 226, 69120 Heidelberg — [6]Physikalisches Institut, Im Neuenheimer Feld 226, 69120 Heidelberg — [7]Physikalisches Institut, Im Neuenheimer Feld 226, 69120 Heidelberg

Time reversal protocols possible one of which is implemented in a dipolar interacting, isolated many-body spin system represented by Rydberg states in an atomic gas. Our time reversal protocol can be used in measurement of Out-of-time-order correlators since time reversal is essential for an OTOC which requires backward evolution of a system which can then be used to measure the extent of information scrambling in the system. However, the dipole-dipole interaction Hamiltonian yields certain second order, perturbative interaction terms which effect the efficiency of our protocol and the fidelity of our measurement. Our goal is to experimentally realize pre-existing theoretical models like a 1-D spin chain to better understand the effect these terms have on our time reversal protocol.

Q 65.8 Thu 17:00 Philo 1. OG

Orientation of Trilobite Rydberg Molecules in Electric Fields — •Markus Exner, Richard Blättner, and Herwig Ott — RPTU Kaiserslautern-Landau, Kaiserslautern, Deutschland

Rydberg molecules consist of a Rydberg atom bound to a ground state atom. The binding mechanism is based on the scattering interaction between the Rydberg electron and the ground state atom. Trilobite molecules are a subclass of high-l Rydberg molecules that exhibit a huge permanent electric dipole moment and are therefore highly sensible to electric fields. We report on the observation of trilobite molecules oriented by an electric field. We excite these molecules within a cloud of ultracold ^{87}Rb atoms using a three-photon excitation scheme. We make the molecules orientation visible on the 2D detector of a reaction microscope taking advantage of state changing collisions.

Q 65.9 Thu 17:00 Philo 1. OG

Towards a global otoc in a rydberg spin system — •Maharshi Pran Bora, Eduard Braun, Meny Menashes, Matthias Lotze, Varad Dhopadkar, Gerhard Zuern, and Matthias Weidemueller — University of Heidelberg

Out-of-time-order correlators (OTOCs) quantify the scrambling of operator information in a quantum system. Most studies formulate this scrambling as a spreading of correlation between local observables in the system. However, the access to these local observables can be challenging sometimes. Interestingly, these correlators can also be studied using global observables of the system. The formulation of multiple quantum coherences and its connection to OTOCs, gives a way to probe the scrambling of global observables in the system [1]. In our Rydberg spin system, we are moving towards measuring this type of global OTOC with a global magnetization measurement. These global OTOC measurements could provide an insight into the localization or thermalization aspects of our rydberg spin system.

[1] Gärttner, M., Hauke, P., & Rey, A. M. (2017). Relating out-of-time-order correlations to entanglement via multiple-quantum coherences. Phys. Rev. Lett. 120, 040402.

Q 66: Poster – Quantum Technologies III

Color Centers and Ion Traps

Time: Thursday 17:00–19:00 Location: Philo 2. OG

Q 66.1 Thu 17:00 Philo 2. OG

SLE-structuring and surface polishing for the fabrication of multi-segmented ion traps — •Jan Christoph Müller[1], Can Leichtweiss[1], Alexander Müller[2], Björn Lekitsch[1,2], and Ferdinand Schmidt-Kaler[1,2] — [1]QUANTUM,Institut für Physik, 55128 Mainz, Germany — [2]neQxt GmbH

The up-scaling of trapped ion quantum computers relies on the segmentation and miniaturization of the traditional macroscopic ion traps to enable the storage of multiple sub clusters of the ions that serve as qubits [1]. We want to achieve this while maintaining favorable qualities like a deep trapping potential and low heating rates at room temperature, both associated with 3D Paul traps. We established a special purpose clean room where we can fabricate trap chips with versatile 3D-geometries in fused silica using Selective Laser-induced Etching (SLE), followed by surface polishing using a scanning CO_2-Laser [2] and metallic sputter deposition. We report on different fabricated trap designs and on tests with $^{40}Ca^+$ ions.

[1] V. Kaushal et al., AVS Quantum Sci.; 2 (1):014101.

[2] C. Weingarten et al., J. Laser Appl.; 29 (1):011702.

Q 66.2 Thu 17:00 Philo 2. OG

Progress on Our Next-Generation Quantum Computing Setup — •James Rumbold[1], Helin Özel[1], Julian Wiener[1], John Wolff[1], Felix Stopp[1,2], Jonas Vogel[1,2], Björn Lekitsch[1,2], and Ferdinand Schmidt-Kaler[1,2] — [1]QUANTUM, Institut für Physik, Johannes Gutenberg-Universität Mainz — [2]NeQxt GmbH

To further enhance the capabilities of trapped-ion quantum computing systems, hundreds of qubits with higher operational fidelities are required. In our next-generation quantum computer we plan to increase our qubit count up to 100 by implementing two independent computational zones, with each holding ten ions and enacting gates simultaneously. Our ion trap features 40 DC segments that can hold additional ion chains and perform transport operations, facilitating all-to-all connectivity. To improve the computational fidelities the setup will feature three layers of mu-metal shielding, no magnetic parts surrounding the vacuum chamber, and a redesigned addressing system for reduced crosstalk. The poster will present the current progress of the experimental system, including optical and electronical qubit control, as well as some preliminary characterisation results of the new components.

Q 66.3 Thu 17:00 Philo 2. OG

Setup of a Confocal Fluorescence Microscope for the Detection and Characterization of Single NV Centers in Diamond — •Manuel Riedmann, Lucas Kirchbach, and Andreas Stute — Technische Hochschule Nürnberg

Single nitrogen vacancy (NV) centers in diamond serve as a photonic platform for quantum sensing and computing applications. They can be created deterministically using femtosecond laser pulses. Such writing process requires high-resolution fluorescence detection with a high signal-to-noise ratio, which is accomplished by setting up a homebuilt confocal fluorescence microscope. The microscope shall monitor the fluorescence of newly formed NV centers during the writing process. In addition, it will be used to characterize the NV centers' spin coherence times, orientation in the diamond lattice and single-emitter characteristics via the intensity correlation function $g^{(2)}(\tau)$. In the future, this setup is also planned to be employed for STED-microscopy of twin NV centers.

Q 66.4 Thu 17:00 Philo 2. OG

Diamond Thin Film Creation for Color Centers — •Nick Brinkmann[1,2], Caius Niemann[1], Donika Imeri[1,2], Leonie Eggers[1,2], Sunil Mahato[1,2], Lasse Irrgang[1], Konstantin Beck[1], Rikhav Shah[1], and Ralf Riedinger[1,2] — [1]Universität Hamburg, Institut für Quantenphysik, Hamburg, Deutschland — [2]The Hamburg Centre for Ultrafast Imaging, 22761 Hamburg, Germany

Diamond nanophotonic structures hold immense potential for breakthroughs in quantum information technologies and are a leading platform for developing quantum memory chips. One challenge in the development of nanophotonic structures lies in the reliable transfer and bonding of single-crystal diamond thin films onto suitable substrates. Here, we present an innovative and scalable process, which holds promise for efficiently and securely managing the transfer of these diamond thin films. This method can advance the fabrication of nanophotonic structures on diamond, which can serve as interfaces between the spins of color centers, such as SiV, and photons. Thus, it opens up new possibilities for integrating such structures into photonic networks, promising significant advances in quantum optics and communication.

Q 66.5 Thu 17:00 Philo 2. OG

Quantum photonics using color centers in a diamond membrane coupled to a photonic structure — •Surena FATEMI[1,2], Jan Fait[1], Roy Konnoth Ancel[2], Christophe Couteau[2], and Christoph Becher[1] — [1]Fachrichtung Physik, Universität des Saarlandes, Saarbrücken, Germany — [2]Université de Technologie de Troyes, Troyes, France

In recent years, color centers in wide band-gap materials have attracted significant attention due to their exceptional potential in quantum technologies. Among these, group-IV color centers in diamond stand out for their long spin coherence times and superior optical properties, including narrow emission lines, high spectral stability, and bright single-photon emission. A key challenge in developing quantum devices based on color centers is the inefficient photon out-coupling from diamond, resulting in low extraction rates. To address this limitation, we investigate group-IV color centers in diamond membranes integrated with TiO2-based photonic waveguides. Leveraging Finite Element Method simulations and Monte Carlo optimization, we refine membrane geometry, coupling interfaces, and waveguide design to enhance photon out-coupling and achieve high photon extraction rates, paving the way for practical, efficient quantum devices. We also present the fabrication process and initial investigations of these optimized structures.

Q 66.6 Thu 17:00 Philo 2. OG

Adhesion Tests for Multi-Layer Surface-Electrode Ion Traps in Cryogenic Ultra-High Vacuum — •Nica Schiffelholz[1], Jacob Stupp[1], Nora D. Stahr[1], Masum M. Billah[1], Marlon Kuhn[1], Christine Marachoris[1], Friederike Giebel[2], Eike Iseke[1,2], Nila Krishnakumar[1,2], Konstantin Thronberens[2], and Christian Ospelkaus[1,2] — [1]Institute for Quantum Optics, Leibniz University Hannover, Welfengarten 1, Hannover, 30167, Germany — [2]Physikalisch-Technische Bundesanstalt, Bundesallee 100, Braunschweig, 38116, Germany

Quantum computers are expected to solve certain computational problems significantly faster than classical computers. Trapped-ion based approaches offer the advantage of scalability and low error rates. Trapping ions in surface-electrode ion traps offers improved optical access, while multi-layered designs allow more complex signal routing in multifunctional trap designs. In our design, subsequent gold layers are microfabricated with a dieletric polyimide film between each level. Here we investigate the adhesive behavior between the polyimide layer and the subsequent layers for use in cryogenic ultra-high vacuum under varying manufacturing parameters. Titanium and chromium are tested as adhesive layers, and their effect on the gold layer is studied.

Q 66.7 Thu 17:00 Philo 2. OG

Characterization of shallow, low temperature annealed tin-vacancy centers in diamond — •Gabrielle A. Hunter-Smith, Jan Fait, Kilian Mark, Surena Fatemi, and Christoph Becher — Universität des Saarlandes, Fachrichtung Physik, Campus E2 6, 66123 Saarbrücken

Group-IV color centers in diamond are well known for their suitability as nodes within quantum networks due to their excellent spin and optical coherence. In particular the negatively charged tin-vacancy center (SnV-) has proved promising, with previous work showing that after high pressure, high temperature (HPHT) annealing, the spread of spectral peaks may be significantly reduced [1].

However, HPHT annealing is both a costly and restrictive procedure, as well as being potentially destructive to delicate surface structures, e.g. nano-photonic elements.

We here present initial investigations on shallow SnV- centers generated by focused ion beam implantation and annealing under vacuum at 1200°C. In particular, we consider the effects of surface terminations and etched microstructures on the surface of thin diamond samples through monitoring the emission spectra, saturation curves, and background fluorescence levels.

[1] Görlitz, J. et al, 2020 New J. Phys. **22** 013048

Q 66.8 Thu 17:00 Philo 2. OG

Adaption and Evaluation of Custom Microwave Antennas for NV Center Coherence Measurements — •Yannick Resch, Anish Thomas, Stefan Johansson, Dennis Lönard, Alena Erlenbach, Jonas Gutsche, and Artur Widera — Department of Physics and State Research Center OPTIMAS, RPTU University Kaiserslautern-Landau, 67663 Kaiserslautern, Germany

Due to their biocompatibility, nitrogen-vacancy (NV) centers in diamonds can be implanted into cells and algae to investigate magnetic-field signals and temperatures inside these biological samples. The sensitivity of the magnetic field and temperature sensing with NV centers is, however, often limited by the inhomogeneity of the microwave field used to drive the NV centers' spin states.

In this work, we report on the adaptation and evaluation of different designs of microwave patch antennas tailored for integration into an existing setup for probing biological samples. We investigate a double split-ring resonator and a planar ring design for their ability to generate homogeneous microwave fields and their efficiency in exciting the spin-resonance transitions of NV centers.

To achieve suitable impedance characteristics and field distribution, we used high-frequency simulations and characterized the resulting prototypes by experimental S-parameter analysis as well as magnitude and homogeneity of the microwave field, which was determined by measuring Rabi oscillations in several NV-diamond specimens.

Q 66.9 Thu 17:00 Philo 2. OG

Exploring Nickel Vacancies for Improved Colour Centres — •Florian Rickert, Nick Brinkmann, Caius Niemann, and Ralf Riedinger — Institute for Quantum Physics, Hamburg, Germany

As quantum computers advance, the need for quantum networks becomes more apparent. In order to realize a quantum internet, we need to connect processors over long distances. With quantum cryptography, security levels in communication could then be raised to unprecedented levels.

Due to the exponential loss of photons in fibers over long distances, an optical quantum network relies on quantum repeaters that allow for qubit storage with sufficiently long coherence times. A thoroughly investigated platform for such repeaters is the silicon-vacancy (SiV-) color center in diamond. At temperatures below 100 millikelvin, this defect exhibits spin memory long enough to enable entanglement over a distance of 500 kilometers. The major drawback of this platform, despite its impressive performance, is the extremely low temperature requirement which demands expensive dilution refrigeration.

A promising candidate to overcome this limitation is the NiV color center in diamond. Due to stronger spin-orbit coupling, the ground state splitting of Nickel is larger, making the spin qubit stable at temperatures up to about 2K. These temperatures are reached with a much more affordable and transportable setup.

Here we present recent efforts for chip integration of NiV color centers.

Q 66.10 Thu 17:00 Philo 2. OG

Time-resolved coherent optical spectroscopy on an ensemble of tin-vacancy color centers in diamond — •Fabian Voltz, Anna Fuchs, and Christoph Becher — Universität des Saarlandes, Saarbrücken 66123, Germany

Single negatively charged group IV-vacancy (G4V) color centers in diamond are among the leading candidates for qubit systems in quantum communication due to their long spin coherence times and stable optical emission lines. While most studies focus on single centers, dense ensembles of G4V centers offer enhanced light-matter coupling, as shown for ensembles of silicon-vacancy (SiV^-) centers [1], enabling applications such as Raman-based quantum memories or quantum sensing.

Among the G4V centers, single tin-vacancy (SnV^-) centers stand out with long spin coherence times at elevated temperatures (~ 2 K) [2,3]. However the spin dynamics of ensembles of SnV^- centers remain largely unexplored, despite the potential benefits of higher signal levels.

In this work, we investigate the spin coherence time of a dense SnV^- ensemble by combining coherent optical spectroscopy with time-resolved measurements. We will present our recent results on SnV^- ensembles and discuss the implications of these findings for ensemble-based quantum technologies that aim to combine strong light-matter interaction with long spin coherence.

[1] Weinzetl et al., Phys. Rev. Lett. 122, 063601 (2019)
[2] Karapatzakis et al., Phys. Rev. X 14, 031036 (2024)
[3] Görlitz et al., npj Quantum Inf 8, 45 (2022)

Q 66.11 Thu 17:00 Philo 2. OG

Scalable formation of tin-vacancy centers in diamond for quantum technology applications. — •Aikaterini Tzanetou[1], Felix Hoffmann[1], Ella Schneider[2], Gianfranco Aresta[3], Mukesh Triparthi[4], Julian Rickert[4], and Daniel Hähnel[1] — [1]Fraunhofer Institute for applied Solid State Research IAF, Freiburg, 79108, Germany — [2]Surrey Ion Beam Centre, University of Surrey, Guildford GU2 7XH, UK — [3]Ionoptika Ltd.B6 Millbrook Close, Chandler's Ford, Hampshire SO53 4BZ, UK — [4]XeedQ GmbH, Augustusplatz 1-4, 04109 Leipzig, Germany

The tin-vacancy (Sn-V) center in diamond has emerged as a promising emitter for the realization of quantum information processing protocols. We here report on a process flow that targets the precise, reproducible and localized formation of tin-vacancy centers in diamond intended for use in quantum technology applications. On this basis, tin ions (117-Sn2+) are implanted on high-purity diamond substrates by means of focused-ion-beam single-ion implantation. The implantation pattern consists of 100-spot arrays each formed by discrete number of ions per spot. Thermal annealing in vacuum is applied for the color center generation and consequently the defects are studied with optical characterization tools. Localization at the nanoscale with spot sizes below 90 nm is reported from stimulated emission depletion (STED) microscopy measurements. Spectral analysis and photoluminescence intensity measurements provide insights on Sn-V formation as a function of ion fluence. The process flow is evaluated in a statistical framework with a focus on scalability and process yield.

Q 66.12 Thu 17:00 Philo 2. OG

A Modular Multi-Card AWG Platform for High-Fidelity Control of Segmented Ion Traps — •Maximilian Orth[1,2], Björn Lekitsch[1,2], and Ferdinand Schmidt-Kaler[1,2] — [1]QUANTUM, Institut für Physik, Johannes Gutenberg-Universität Mainz — [2]neQxt GmbH

We present a new modular AWG platform for segmented ion traps, implemented as a multi-card system within a single chassis. DC-AWG, RF-AWG and main-controller cards are interconnected via a shared backplane, forming a freely scalable control architecture. The fully linear output behaviour allows for compensation and accurate modelling of the output distortion behind the trap*s filter network.

The DC-AWG cards provide 32 channels per module and a +-40V output. The main-controller card supplies deterministic digital I/O and system-wide timing with an update rate of 20ns, while the RF-AWG card generates the frequency-agile signals required for AOM/AOD-based laser-driven qubit gate operations. We also implement branching and looping, conditioned on counter input signals as required e.g. for quantum error correction. The DC AWG low noise floor enable accurate qubit register reconfiguration operations in complex shuttle-based trapped ion quantum processor architectures. This includes the transport, splitting/merging with multi-ion crystals.

Q 66.13 Thu 17:00 Philo 2. OG

High Frequency Ion-Photon Interfaces for Distributed Quantum Computing — •Lasse Jens Irrgang, Luca Graf, Cathérine Matthies, Hannah Koeth, Tuncay Ulaş, Rikahv Shah, and Ralf Riedinger — Zentrum für Optische Quantentechnologien, Universität Hamburg, 22761 Hamburg, Germany

Decades of excessive research have proven the key towards a quantum advantage of quantum computing compared to classical computers is the scalability of the quantum processor. In analogy to classical super computing clusters we propose a network of small interconnected trapped-ion-based quantum processors to achieve flexibly scalable quantum computing.

In detail, a fibre-based Fabry-Pérot cavity integrated in an ion-trap provides an efficient ion-photon interface. This enables entanglement of ion-qubits in spatially separated traps at a high frequency, and therefore distributed computing in a network of ion-based quantum processors.

Being per se platform-independent, the concept is firstly demonstrated connecting a room-temperature blade trap and a cryogenic blade trap. A novel blade-integrated design of the fibre-cavity ensures plenty of free-space access for cooling and operation lasers. To cope with accumulating charges in the dielectric glass-fibres, disturbing the trapping field, an in-house designed conductive coating applied to the fibres circumvents these effects.

Q 66.14 Thu 17:00 Philo 2. OG

Addressed Raman Gates in a Shuttling-based Architecture — •Daniel Wessel[1,2], Robin Strohmaier[1], Tabea Stroinski[1], Janis Wagner[1], Ulrich Poschinger[1,2], and Ferdinand Schmidt-Kaler[1,2] — [1]QUANTUM, Institut für Physik, Johannes Gutenberg-Universität Mainz — [2]neQxt GmbH

High-fidelity, individually addressed quantum gates are a central requirement for scalable trapped-ion quantum information processing. In this poster, I present the implementation of addressed Raman gates on $^{40}Ca^{+}$ ions confined in a 3D segmented Paul trap, enabled by UV Raman beams and fast beam steering using acousto-optic deflectors (AODs). The 3D trap architecture provides enhanced optical access and precise control of ion positioning, while the segmentation allows for flexible ion shuttling and reconfiguration of computational zones [1]. We demonstrate site-selective Raman interactions using tightly focused UV beams at 395 nm, achieving high spatial discrimination between ions and minimizing crosstalk through optimized beam geometry and AOD-driven dynamic addressing. Our results show that AOD-based UV addressing is a powerful and scalable approach for parallel gate operations in advanced ion-trap architectures, and we outline pathways for extending this technique to larger arrays and modular quantum computing platforms.

[1] Kaushal, et al. *AVS Quantum Sci. 2*, 014101 (2020)

Q 66.15 Thu 17:00 Philo 2. OG

Manufacturing of Highly Integrated Ions Traps for Quantum Computing — •Marlon Kuhn[1], Jacob Stupp[1], Nora D. Stahr[1], Masum Billah[1], Nica Schiffelholz[1], Christine Marachoris[1], Friederike Giebel[1,2], Eike Iseke[1,2], Nila Krishnakumar[1,2], Konstantin Thronberens[2], and Christian Ospelkaus[1,2] — [1]Institute for Quantum Optics, Leibniz University Hannover, Welfengarten 1, Hannover, 30167, Germany — [2]Physikalisch-Technische Bundesanstalt, Bundasallee 100, Braunschweig, 38116, Germany

Trapped ions are one of the most promising platforms for the implementation of quantum computing and quantum simulations. For demanding computation, a scalable device, capable of trapping, manipulating, moving and cooling trapped ions is needed. Microfabricated surface electrode traps (Paul traps) are ideally suited for these applications. We present an overview on our manufacturing methods and how to overcome upcoming problems that come with scaling these devices to higher densities to accommodate more ions. We also present strategies for integration of further functionalities like permanent magnets, microwave electrodes or integrated photonics, to enhance the scalability of trapped ion systems.

Q 66.16 Thu 17:00 Philo 2. OG

Design and implementation of a multi-segment Paul trap — •Franz Krieger[1], Lara Becker[1], Stephan Kucera[1,2], Jan C. Müller[3], and Jürgen Eschner[1] — [1]Universität des Saarlandes, Experimentalphysik, 66123 Saarbrücken, Germany — [2]Luxembourg Institute of Science and Technology, 4362 Belvaux, Luxembourg — [3]Johannes Gutenberg Universität Mainz, 55122 Mainz, Germany

Single trapped ions as quantum memories and single photons as quantum information carriers are promising building blocks for quantum networks, enabling high-fidelity entanglement through controlled single-photon absorption and emission [1]. Ion-photon interfaces are thus well-suited for quantum repeaters [2] and linking quantum processors into quantum computing networks. We are developing a multi-segment linear Paul trap for $^{40}Ca^{+}$ ions, fabricated from glass with a segmented metal-coated electrode structure. This design addresses pitfalls encountered in the previous segmented ferrule trap [3], offering improved mechanical stability, and more flexible fabrication. The new setup also allows integration of a fiber cavity for efficient photon collection and generation. In the first prototype, the trap is implemented without the cavity. The compact design enables the entire system, including the vacuum chamber, control electronics, and ablation and photo-ionization lasers, to fit within a single transportable rack.

[1] E. Arensktter et al., npj Quantum Inf. 9, 34 (2023).
[2] M. Bergerhoff et al., Phys. Rev. A 110, 032603 (2024).
[3] L. Becker et al., poster Q 62.9, DPG Spring Meeting, Bonn (2025).

Q 66.17 Thu 17:00 Philo 2. OG

Rack-mounted ion trap with integrated fiber cavity — •Lara Becker[1], Jolan Costard[1], Stephan Kucera[1,2], and Jürgen Eschner[1] — [1]Universität des Saarlandes, Experimentalphysik, 66123 Saarbrücken, Germany — [2]Luxembourg Institute of Science and Technology, 4362 Belvaux, Luxembourg

Single trapped ions as quantum memories and single photons as quantum information carriers are promising building blocks of quantum networks [1], providing high-fidelity entanglement in controlled single-photon absorption and emission [2]. Ion-photon interfaces are thus a promising platform for implementing a quantum repeater and for connecting quantum processors into a quantum computing network.

Our experimental setup is a multi-segment Paul trap for $^{40}Ca^{+}$ ions with an integrated fiber cavity to increase the photon collection and generation efficiency of the interface. The trap consists of two laser-machined and metal-coated ceramic ferrules, into which the fiber cavity with sub-mm spacing is integrated. In a first prototype we integrated a cavity with $220\,\mu$m length and 8000 finesse with a trap of $190\,\mu$m electrode separation. The trap, together with a laser-beam distribution system, detection optics and control electronics, is mounted in a 19-inch rack. Its future implementation will enable quantum repeater protocols [3] over the Saarbrücken fiber link [4].

[1] M. Bock et al., Nat. Commun. 9, 1998 (2018)
[2] E. Arenskötter, et al., npj Quantum Inf. 9, 34 (2023)
[3] M. Bergerhoff, et al., Phys. Rev. A 110, 032603 (2024)
[4] S. Kucera, et al., npj Quantum Inf. 10, 88 (2024)

Q 66.18 Thu 17:00 Philo 2. OG

Advanced fabrication and characterization of solid immersion lenses in diamond and silicon carbide — •Alexander Spyrantis[1,2], Anna Mogilatenko[1], Kilian Unterguggenberger[2], Stefan Facsko[3], Bailiang Li[4], Gerhard Hobler[4], Tommaso Pregnolato[1,2], Tim Schröder[1,2], and Katja Höflich[1,2] — [1]Ferdinand-Braun-Institut (FBH), 12489 Berlin, Germany — [2]Humboldt-Universität zu Berlin, Institut für Physik, 12489 Berlin, Germany — [3]Helmholtz-Zentrum Dresden-Rossendorf, 01328 Dresden, Germany — [4]Technische Universität Wien, 1040 Wien, Austria

Solid immersion lenses (SILs) are hemispherical microstructures that increase the light collection efficiency of defect-based quantum emitters in high refractive index materials like diamond and silicon carbide. They can be created by focused ion beam (FIB) milling in a mask-less approach.

Previous attempts required post-processing and lacked reproducibility due to beam damage and redeposited material at the side walls. Using a continuous spiral pattern, we resolved those issues and achieved SILs with optimal curvature, yielding a 8.5-fold improvement in the light collection efficiency for NV centers in diamond.

Depending on the ion beam energy, step edges of different sizes form at the side walls of the lens. This is studied using continuum and binary collision modeling. In line with the predictions from modeling, microstructural characterization shows only a thin amorphization layer on the intact crystalline material due to the suppressed redeposition.

Q 66.19 Thu 17:00 Philo 2. OG

Surface-Electrode Ion Trap Design with Chip-Integrated Microwave Conductors for Near-Field Microwave Quantum Control — •Janina Bätge[1], Florian Ungerechts[1], Rodrigo Munoz[1], Masum Billah[1], Phil Nuschke[1], Axel Hoffmann[2], Giorgio Zarantonello[3], and Christian Ospelkaus[1,4] — [1]Institut für Quantenoptik, Leibniz Universität Hannover, Germany — [2]Institut für Hochfrequenztechnik und Funksysteme, Leibniz Uiversität Hannover — [3]Qudora Technologies GmbH, Braunschweig, Germany — [4]Physikalisch-Technische Bundesanstalt, Braunschweig, Germany

Surface-electrode ion traps are a promising platform for scalable quantum computers. In the Quantum CCD architecture, transport of ions between registers allows to limit the number of ions that has to be kept in a single potential well at any given time and to implement specialized registers for storage, cooling, detection and gate operations. Here we present the design of a demonstrator chip based on an X junction and quantum gate operations with chip-integrated microwave conductors. This design has been developed with the goal of increasing the storage capacity, optimizing laser access and improving gate operations.

Q 66.20 Thu 17:00 Philo 2. OG

Towards notch-filtered adiabatic rapid passage non-resonant coherent excitation scheme in vacancy centres in diamond — •Leon Reichgardt[1], Cem Güney Torun[1], and Tim Schröder[1,2] — [1]Department of Physics, Humboldt-Universität zu Berlin, 12489 Berlin, Germany — [2]Ferdinand-Braun-Institut, Leibniz-Institut für Höchstfrequenztechnik, 12489 Berlin, Germany

Group-IV color centers in diamond have emerged in the past decade as a hardware so- lution for quantum repeaters to transmit quantum information over long distances. One of the key required ingredients is the generation of on-demand indistinguishable single photons. When using optical resonant excitation, one of the challenges faced is that the photons used for excitation cannot be distinguished from the photons emitted by the color center. We report on the experimental implementation of the off-resonant excitation scheme, notch-filtered adiabatic rapid passage (NARP), in the SnV center. The scheme is based on an up-chirped pulse with a notch-filtered spectral component overlapping with the targeted resonance frequency. For the collection of the single photons, the scattered excitation pulse is suppressed using a bandpass filter. This excitation scheme is suitable for emitters in a cavity with a large Purcell factor and short lifetimes due to the broadband nature of the laser pulse. Applying NARP to SnV centers introduces a novel excitation technique from the ex- tended toolbox of quantum optics to diamond color centers..

Q 66.21 Thu 17:00 Philo 2. OG

An Interface Concept for Ion Quantum Computers: Fiber-Based Cavities for Enhanced Optical Connection — •Luca Graf, Lasse Irrgang, Catherine Matthies, Hannah Koeth, Tuncay Ulas, and Ralf Riedinger — Zentrum für optische Quantentechnologien, Universität Hamburg, 22761 Hamburg, Germany

The development of quantum computers promises to solve computational complex problems in the future that cannot be solved with classical computers. Just as in conventional computing clusters, quantum computers must also be networked in a scalable way. We present an innovative concept for an interface that has been specially developed for ion quantum computers. This approach uses special coated fiber-based cavities to establish an efficient optical connection between ion traps. Furthermore, this approach can be used to couple optical qubits, such as entangled photons, with ions in the trap. For our experiments, we will utilize barium ions as qubits and ytterbium ions as sympathetically cooled reference ions.

Q 66.22 Thu 17:00 Philo 2. OG

Highly Indistinguishable Single Photons from Tin-Vacancy Centers in Diamond — •Dennis Herrmann[1], Robert Morsch[1], Detlef Rogalla[2], Matthew Markham[3], and Christoph Becher[1] — [1]Fachrichtung 7.2, Universität des Saarlandes, Campus E2.6, 66123 Saarbrücken, Germany — [2]RUBION, Ruhr-Universität Bochum, Universitätsstraße 150, D-44801, Bochum, Germany — [3]Element Six Global Innovation Centre, Fermi Avenue, Harwell Oxford, Didcot, Oxfordshire, OX11 0QR, UK

The tin-vacancy (SnV) center in diamond has emerged as a powerful platform for photonic quantum technologies offering bright and spectrally stable single-photon emission together with optically addressable spin states that reach coherence times of up to 10 ms under dynamical decoupling. By combining a cross-polarization excitation scheme with polarisation-based laser suppression exceeding seven orders of magnitude and driving the emitter with coherent 180 ps optical pulses, we demonstrate two-photon quantum interference of consecutively emitted, highly indistinguishable single photons on the C-transition. Under these conditions, we obtain raw Hong-Ou-Mandel visibility values above 95 % at photon generation rates up to 3000 Hz, together with raw single-photon purities below 0.02. These results represent a key advancement towards a functional spin-photon interface - an essential component for quantum repeaters, large-scale quantum networks, and photonic cluster-state generation.

Q 66.23 Thu 17:00 Philo 2. OG

Quantification of Spectral Diffusion Rate for Tin-Vacancy Quantum Emitters in Low-Temperature Annealed Diamond — •Linus Ehre, Dennis Herrmann, and Christoph Becher — Fachrichtung Physik, Universität des Saarlandes, Campus E2.6, D-66123, Germany

The Tin-Vacancy color center (SnV) in diamond is a promising candidate as a solid-state quantum network node, emitting highly indistinguishable lifetime-limited photons.

While the SnV's inversion symmetry in an ideal diamond lattice prevents first-order Stark shifts, a high defect-density causes distortions of this ideal structure. Consequently, the SnV becomes more susceptible to spectral diffusion (SD) in fluctuating charge environments, broadening the optical transition. High-pressure high-temperature (HPHT) annealing at $T = 2100\,^{\circ}C$ minimizes this effect, but causes damage by graphitizing the surface. In contrast, annealing at lower temperatures (LT), i.e. $T = 1200\,^{\circ}C$ for up to 80 hours is a more accessible method and mostly leaves the diamond surface intact. However, this LT-treatment appears to be less effective in suppressing spectral diffusion, due to remaining symmetry distortions and charge traps.

In this work, we present a method to determine the SD rate for single SnV centers in an LT-annealed diamond sample. Variation of experimental conditions allows for a comparison to HPHT-treated diamonds and thus an evaluation of possible tradeoffs. Our results offer key insights into the LT-treated SnV's suitability as a stable high-quality photon source for future quantum network applications.

Q 66.24 Thu 17:00 Philo 2. OG

Towards sympathetically cooled qubits in a 30-qubit X-junction chip — •Kevin Rempel[1], Vanessa Wienzek[1], Markus Duwe[1,2], Sascha Agne[2], Celeste Torkzaban[1], and Christian Ospelkaus[1,2] — [1]Institut für Quantenoptik, Leibniz Universität Hannover, Welfengarten 1, 30167 Hannover, Germany — [2]Physikalisch-Technische Bundesanstalt, Bundesallee 100, 38116 Braunschweig, Germany

Featuring high fidelities, long coherence times and all-to-all interconnectivity of qubits, surface-electrode ion traps represent a promising physical platform for realizing a universal quantum processor for quantum computing and simulation. In our experiment, we encode qubits using a hyperfine transition in $^{9}Be^{+}$ ions that is magnetic-field insensitive to first order. The internal and motional states are manipulated by trap-integrated microwave conductors.

We will upgrade our experiment with a cryogenic X-junction-style trap chip which will allow us to handle up to 30 qubits. It includes independent storage, detection and gate zones. To improve gate fidelities and extend the number of gates we can run before directly re-cooling the qubits, we are preparing to use $^{40}Ca^{+}$ ions to sympathetically cool our $^{9}Be^{+}$ qubits by coupling specific motional modes of the ion crystal. This can be achieved by resonantly tuning the third-order Coulomb interaction or by applying oscillating electric potential modulations to the existing confining trap potential. We will report on our simulation results and the necessary hardware modifications.

Q 66.25 Thu 17:00 Philo 2. OG

Hybrid platform for cavity enhanced SnV centres for quantum applications — •Victoria Voinkova[1], Georgii Grechko[1], Jonathan Ensslin[1], Roman Kolesov[1], Vadim Vorobyev[1], and Jörg Wrachtrup[1,2] — [1]3. Physics Institute, University of Stuttgart, Germany — [2]Max Plank Institute of Solid State Research, Stuttgart, Germany

The tin-vacancy colour centre in diamond (SnV) has emerged as a highly promising constituent for next-generation quantum networks owing to its outstanding optical and spin characteristics. High rates of coherent emission are pivotal for obtaining big cyclicity and realising the effective communication protocols. Coupling emitters to the resonance structures is a compelling mechanism for light-matter interaction enhancement, efficiency of which is proven by numerous recent research, illustrated with (but not limited to) nanobeam and 2D photonic crystal cavities, open microcavities and ring resonators. However, maturing of this technology is hindered by fabrication methods, scalability and robustness of which is still being a challenging topic. Here we propose the scalable method of fabrication of the diamond photonic devices, scalability of which stems from the hybrid integration with electrooptically tunable platform of Thin Film Lithium Niobate. The proposed method combines the *SnV - friendly* manufacturing flow, wide variety of tuning options and perspectives for further photonic device interconnection on one chip. This would be an important step towards creating diamond colour centre based quantum network infrastructure.

Q 66.26 Thu 17:00 Philo 2. OG

Creation of Group IV color centers — •Kathrin Schwer[1], Selene Sachero[1], Emilio Corte[2], Elena Nieto Hernandez[2], Jens Fuhrmann[1], Sviatoslav Ditalia Tchernij[2], Fedor Jelezko[1], and Alexander Kubanek[1] — [1]Ulm University, Ulm, Germany — [2]Turin University, Turin, Germany

Efficient coupling between quantum emitters and optical cavities is essential for scalable quantum photonic technologies. Group IV vacancy centers in diamond have emerged as promising candidates due to their spectral stability, high Debye-Waller factor and large orbital splitting in groundstates. Reduction of the diamond host size to the nanoscale enables new opportunities in terms of integration and scalability. However, creating optically coherent quantum emitters in nanodiamonds remains a major challenge. Here, we present the fabrication ofGroup IV color centers by means of ion implantation and describe the optical properties of the created color centers. We achieve high-purity singlephoton emission via resonant excitation and strong coherent drive. The obtained results demonstrate the potential of Group IV centers in nanodiamonds as a coherent single-photon source for quantum networks.

Q 66.27 Thu 17:00 Philo 2. OG

Recent results and ongoing developments in microwave-driven trapped-ion quantum computing experiments — •Erik Dunkel[1], Najwa Al-Zaki[1], Tobias Pootz[1], David Stuhrmann[1], Radhika Goyal[1], Sascha Agne[2], Celeste Torkzaban[1], and Christian Ospelkaus[1,2] — [1]Leibniz Universität Hannover, Welfengarten 1, 30167 Hannover — [2]Physikalisch-Technische Bundesanstalt, Bundesallee 100, 38116 Braunschweig

Trapped ions are a highly promising platform for both quantum computing and quantum simulation. We utilize surface-electrode ion traps with integrated microwave conductors to trap ions and drive qubit rotations and entangling gates by manipulating the internal and motional states of the ions.

Our qubit transitions for $^{9}Be^{+}$ and $^{43}Ca^{+}$ feature first-order magnetic field insensitive hyperfine transitions. We will share results of the simultaneous trapping of different ion species in our cryogenic apparatuses, which is an essential step towards implementing sympathetic cooling. In addition, we will discuss the steps made towards implementing a junction-style trap chip, so that we can transport ions between storage, quantum logic and detection zones, along with our plan for testing and characterizing a waveguide chip in a second apparatus.

Q 66.28 Thu 17:00 Philo 2. OG

Toward a Scalable NV-Based Quantum Processor: Fiber Interconnects in Diamond Photonics — •Leon Büttner, Lara Ruppert, Christian Giese, Rebekka Eberle, and Daniel Hähnel — Fraunhofer Institute for Applied Solid State Physics, Freiburg im Breisgau, Germany

Heterogeneously integrated NV centers in photonic structures hold great promise for scalable, fiber-connected quantum information processing. We pursue a diamond-based photonic platform that combines efficient spin control, stable NV emission, and robust optical outcoupling to enable a modular, fiber-connected quantum processor. We explore strategies for vertical optical outcoupling in small-footprint NV-containing diamonds to achieve efficient, localized readout of NV centers. Together with microwave structures, this yields a modular device addressing the photonic and electronic challenges of an NV device. Fiber integration obviates the free-space optical path, creating a robust platform for quantum information processing. Future work could target heterogeneously integrating fiber-to-chip coupling, including lithographically defined spin-control structures, to drive toward a scalable NV-based quantum processor.

Q 66.29 Thu 17:00 Philo 2. OG

Femtosecond-Laser Written Waveguides and Surface Structures for High-Efficiency NV-Center Fluorescence Collection in Diamond — Andreas Giese[1], Lucas Kirchbach[1], Andreas Stute[1], Stefan Nolte[2], and •Bernd Braun[1] — [1]Technische Hochschule Nürnberg, Nuremberg, Germany — [2]Friedrich-Schiller-Universität Jena, Jena, Germany

Nitrogen-vacancy (NV) centers in diamond are a promising platform for applications in optical quantum technologies such as quantum sensing and quantum computing. In addition to the precise and deterministic fabrication of NV centers in diamond using direct laser writing, efficient fluorescence collection is of crucial importance.

We investigate strategies for the enhancement of photon extraction from NV-centers in diamond. Directly laser written waveguides inside the diamond crystal enable efficient coupling and potential fiber-based detection for integrated photonic architectures. Numerical simulations support the experiments and are used for the optimization of the volume modifications. Further approaches for increasing the collected fluorescence are based on laser structuring of the diamond surface, for example through the fabrication of microlenses to enhance the extraction of emitted photons. These methods provide pathways toward highly efficient, scalable collection schemes for diamond-based quantum photonic devices.

Q 66.30 Thu 17:00 Philo 2. OG

Nuclear-nuclear Bell-state preparation of ^{13}C nuclear spins coupled to a negatively charged silicon vacancy (SiV^{-}) center. — •David Opferkuch[1,2], Marco Klotz[1], Andreas Tangemann[1], and Alexander Kubanek[1,2] — [1]Institute for Quantum Optics, Ulm University, Albert-Einstein-Allee 11, 89081 Ulm, Germany — [2]Center for Integrated Quantum Science and Technology (IQST), Ulm University, Albert-Einstein-Allee 11, Ulm 89081, Germany

Due to presumed high scalability, spin qubits in solid state hosts are promising candidates for the realization of quantum networks. As such, negatively charged silicon-based vacancy centers (SiV^{-}) in nanodiamonds (ND) combine the good spin properties of diamond as a host with the good optical properties of group-IV defects.

We are using highly strained SiV^{-} in ND, which demonstrate orbital ground state splittings exceeding 1THz. Thus, phonon induced dephasing of the spin qubit is mitigated at liquid Helium temperatures. We have demonstrated coherent control of up to three ^{13}C nuclear spins coupling to a single SiV^{-}. Here we present nuclear-nuclear spin entangling in the three qubit register. A Bell-state between two nuclear spins is created using a 2π-gate. We thus demonstrate reliable nuclear-nuclear spin entanglement for use in a three-qubit quantum memory architecture.

[1] M. Klotz et al., https://arxiv.org/pdf/2508.05255, (2025)
[2] M. Klotz et al., npj Quantum Inf. 11, 91 (2025)

Q 66.31 Thu 17:00 Philo 2. OG

Investigation of the Dynamic 14N Nuclear Spin Polarization at Different Magnetic Field Strengths and Angles in Nitrogen-Vacancy Ensemble in Diamond — •Glen Neiteler[1], Jonas Homrighausen[1], Dennis Stiegekötter[2], Ludwig Horsthemke[2], Peter Glösekötter[2], and Markus Gregor[1] — [1]Department of Engineering Physics, FH Münster University of Applied Sciences, Stegerwaldstr. 39, 48565 Steinfurt, Germany — [2]Department of Electrical Engineering and Computer Science, FH Münster University of Applied Sciences, Stegerwaldstr. 39, 48565 Steinfurt, Germany

The spin-states of the nitrogen-vacancy (NV) centers in diamond can be studied and manipulated at room temperature and optically read out, making them uniquely suitable for low-cost quantum education kits, like a 3D-printed modular setup for quantum sensing or for coherent control experiments. As a first step toward developing a new educational kit for controlling the electron-nuclear spin interaction, we aim to demonstrate the 14N nuclear spin polarization in NV ensemble in diamond. Thus, we experimentally investigate dynamic 14N nuclear spin polarization at small magnetic field angles and angles larger than 2 °, which have not yet been reported in literature, for various magnetic field strengths from 0-60 mT, covering the region of excited-state level anticrossing. This study helps us to identify a compromise between sufficient 14N nuclear spin polarization, magnetic field strength and magnetic field orientation for development our new educational kit.

Q 66.32 Thu 17:00 Philo 2. OG

A Quantum Frequency Conversion Interface for Silicon Vacancy based Quantum Networks — •Konstantin Beck[1], Donika Imeri[1,2], Leonie Eggers[1,2], Lasse Irrgang[1], Nick Brinkmann[1,2], Sunil Mahato[1,2], Rikhav Shah[1], Roman Schnabel[1,2], and Ralf Riedinger[1,2] — [1]Zentrum für Optische Quantentechnologien, Universität Hamburg, 22761 Hamburg, Germany — [2]The Hamburg Centre for Ultrafast Imaging, 22761 Hamburg, Germany

Silicon vacancy (SiV) centers in diamond have shown great potential for applications in quantum sensing and quantum communication, due to their optically addressable spin transitions and stability against noise. At temperatures below 300 mK, the SiV has a long-lived spin degree of freedom that enables its use as a quantum network node.

We propose a high bandwidth quantum frequency conversion (QFC) interface for SiV centers in diamond, aimed at enabling their integration into fiber based quantum networks. The concept relies on a one*step conversion process in a compact, doubly resonant cavity, enabling efficient translation of SiV emission into the telecom E*band while preserving quantum coherence. This architecture outlines a pathway toward scalable, SiV based quantum networks and photonic cluster states.

Q 66.33 Thu 17:00 Philo 2. OG

Optical and spin properties of highly strained silicon vacancy centers in diamond host — •Michael Gstaltmeyr[1], Florian Feuchtmayr[1], Robert Berghaus[1], Selene Sachero[1], Gregor Bayer[1], Julia Heupel[2], Tobias Herzig[3], Jan Meijer[3], Cyril Popov[2], and Alexander Kubanek[1] — [1]Institut für Quantenoptik Universitat Ulm — [2]Institute of Nanostructure Technologies and Analytics, Center for Interdisciplinary Nanostructure Science and Technology, University of Kassel — [3]Division of Applied Quantum Systems, Felix Bloch Institute for Solid State Physics, University Leipzig

Spin qubits in solid-state hosts are, due to their promise of scalability, candidates for the realization of quantum networks. The good spin properties of diamond paired with the optical properties of group-IV defects make them of special interest. Using highly strained silicon-vacancy centers effectively decouples the defect spin from the diamond lattice, mitigating disturbing spin dephasing at liquid-helium temperatures. To make use of this type of emitter, the optical and spin properties have to be well understood. This work presents how to create strain up to 500 GHz by bonding a diamond membrane to a DBR mirror and simulates the resulting changes in optical and coherence properties.

Q 67: Poster – Quantum Information

Computing and Simulation; Communication; Concepts and Methods

Time: Thursday 17:00–19:00 Location: Philo 2. OG

Q 67.1 Thu 17:00 Philo 2. OG

Preparation and Control of Logical Qubits in the Hyperfine Structure of ^{173}Yb^{+} — •Selena-Maria Bota, Monika Leibscher, and Christiane P. Koch — Freie Universität Berlin, Berlin, Germany

Recent research proposes robust encoding of quantum information in high angular momentum states of atoms or molecules, where the logical qubits are protected against most common errors [1]. Such codewords can be built in the hyperfine structure of trapped ^{173}Yb^{+}, namely using metastable states in the $^2F^0_{7/2}$ manifold [2]. This work focuses on the preparation of such robust qubits with sequences of microwave pulses, specifically on simulating the population dynamics driven by the pulses and optimising them for better fidelity and time duration. The future aim is to devise a protocol for operational gates using the proposed codewords.

[1] Jain, Shubham P., et al. "Absorption-Emission Codes for Atomic and Molecular Quantum Information Platforms". Phys. Rev. Lett. 133 (2024), p. 260601.

[2] Xiao, Di, et al. "Hyperfine structure of ^{173}Yb^{+}: Toward resolving the ^{173}Yb nuclear-octupole-moment puzzle." Phys. Rev. A 102 (2020), p. 022810.

Q 67.2 Thu 17:00 Philo 2. OG

Updates on the PTB two-qubit quantum computer — •Markus Duwe[1,2], Hardik Mendpara[1,2], Alexander Onkes[1,2], and Christian Ospelkaus[1,2] — [1]Institut für Quantenoptik, Leibniz Universität Hannover — [2]Physikalisch Technische Bundesanstalt, Braunschweig

We report the latest experimental results from the two-qubit quantum processor at PTB. We trap ^{9}Be^{+} ions in a room temperature surface-electrode ion trap. We manipulate the qubits with microwaves generated by conductors embedded in the trap structure [1]. We describe updates to the experimental apparatus and present low heating rates. Individual ions are addressed via a micromotion sideband and the gate infidelity is characterized using randomized benchmarking [2]. We use a Mølmer-Sørensen type interaction to achieve Bell-state infidelities in the 10^{-3} range. Furthermore, we report progress towards combining these two gates to realize a universal gate set with improved performance compared with our previous measurements [3].

Q 67.3 Thu 17:00 Philo 2. OG

Grover Optimization for Lock Scheduling Problems — •Freyja Ullinger[1], Jannes Weghake[1], Oliver Sefrin[1], Sarah Kahlen[2], Lorenz Mumm[2], Tino Werner[2], Sabine Wölk[1], and Matthias Zimmermann[1] — [1]Deutsches Zentrum für Luft- und Raumfahrt e. V. (DLR), Institut für Quantentechnologien, Ulm, Germany — [2]Deutsches Zentrum für Luft- und Raumfahrt e. V. (DLR), Institut für Systems Engineering für zukünftige Mobilität, Oldenburg, Germany

There exist several quantum algorithms with a proven quantum advantage. One of them is the Grover Search Algorithm [1], which finds an item in an unordered database with quadratic speed-up. By mapping optimization problems to search problems, one is able to harvest this quantum advantage. A particularly interesting NP-hard problem explored in the project QCMobility is the lock scheduling problem. Here we aim at deriving an optimal schedule to lock the incoming ships, while minimizing for example waiting times or water consumption.

In this poster, we investigate the solution of the lock scheduling problem. For this purpose, we formulate it as a quadratic unconstrained binary optimization (QUBO) problem and find the global optimum with Grover Adaptive Search [2]. Our results are obtained on quantum hardware simulators.

[1] L. K. Grover, Proc. 28th Annu. ACM Symp. Theory Comput., 212 - 219 (1996).

[2] W. P. Baritompa, D. W. Bulger, and G. R. Wood, SIAM J. Optim. **15**, 1170 (2005).

Q 67.4 Thu 17:00 Philo 2. OG

A guide on Grover search algorithms for solving QUBO problems — •Jannes Weghake, Freyja Ullinger, and Matthias Zimmermann — Deutsches Zentrum für Luft- und Raumfahrt e.V. (DLR), Institut für Quantentechnologien, Ulm, Germany

Typical industry-related optimizations, like routing, packing, or scheduling, can be reformulated as a quadratic unconstrained binary optimization (QUBO) problem [1]. In the fault-tolerant quantum computing era, a promising approach to solve these problems is the Grover Adaptive Search [2]. The Grover Adaptive Search is able to solve QUBOs with a quadratic speed-up in comparison to classical algorithms. Here different Grover runs are chained together in order to identify the optimal solution.

In this poster, we present a comprehensive guide with intuitive visuals, a theoretical background and a walkthrough to help non-expert to apply the Grover Adaptive Search. In particular, we demonstrate how to parse the QUBOs into a Grover oracle - the quantum dictionary [3] - and what this implies for the different quantum registers involved.

[1] G. Kochenberger, J.-K. Hao, F. Glover, M. Lewis, Z. Lü, H. Wang, and Y. Wang, J. Comb. Optim. **28**, 58 (2014).
[2] W. P. Baritompa, D. W. Bulger, and G. R. Wood, SIAM J. Optim. **15**, 1170 (2005).
[3] A. Gilliam, C. Venci, S. Muralidharan, V. Dorum, E. May, R. Narasimhan, and C. Gonciulea, arXiv:1907.11513 (2019).

Q 67.5 Thu 17:00 Philo 2. OG

Quantum Information Processing with trapped-ion based Qudits — •Lukas Gerster, Peter Tirler, Manuel John, Keshav Pareek, Tim Gollerthan, Lisa Parigger, Raphael Poloczek, Timo Spalek, Michael Meth, and Martin Ringbauer — Institut für Experimentalphysik, Universität Innsbruck, Technikerstraße 25/4, 6020 Innsbruck, Austria

Quantum Information Processing has been predominantly developed using qubits, two level quantum systems, as its fundamental building blocks. Most physical implementations of qubit-based quantum processors utilize multilevel systems, from which only two levels are selected for encoding the information. By encoding information in multi-level qudit basis states, one directly expands the Hilbert space available for computation, which promises more efficient compilation with respect to the number of required entangling gates. We experimentally demonstrate a set of local and entangling gate operations on a 10-qudit register, showing all necessary elements for performing qudit-based computation.

Q 67.6 Thu 17:00 Philo 2. OG

Quantum Simulation and Computation with Ytterbium Rydberg Atoms in Optical Tweezer Arrays — •Jonas Rauchfuss[1], Clara Schellong[1], Till Schacht[1], Ben Michaelis[1], Paul Callsen[1], Nejira Pintul[1], Tobias Petersen[1], Alexander Ilin[1], Christoph Becker[1,2], and Klaus Sengstock[1,2] — [1]Center of Optical Quantum Technologies University of Hamburg, Luruper Chaussee 149, 22761 Hamburg — [2]Institute for Quantum Physics, University of Hamburg, Luruper Chaussee 149, 22761 Hamburg

In recent years, neutral atoms have emerged as one of the most promising platforms for quantum computing and quantum simulation, characterised by scalability, large coherence times, high-fidelity single atom control as well as engineerable, strong, long-range interactions. In our project we use the alkaline-earth-like element ytterbium, whose fermionic isotope 171Yb features a rich level structure that allows for sophisticated qubit schemes including midcircuit read-out, advanced error correction, and optical trapping and manipulation of Rydberg states. Here, we introduce our experimental setup and present our current progress towards building a neutral-atom quantum simulator including characterisation measurements of tweezer loading, imaging, and qubit manipulation. We further present efforts to overcome known limitations of current quantum computation and simulation platforms, like arbitrary single atom addressing techniques, efficient suppression of servo induced laser noise for highest fidelity excitation schemes, and fast spatial light modulation techniques for scalable sorting algorithms.

Q 67.7 Thu 17:00 Philo 2. OG

Impact of electrode noise on qubit quality metrics in a 2D segmented ion trap — •Daniel Busch[1], Benjamin Bürger[1], Kais Rejaibi[1], Ivan Boldin[1,2], Patrick Huber[1], Dorna Niroomand[1], and Christof Wunderlich[1] — [1]Universität Siegen, Walter-Flex-Straße 3, 57072 Siegen — [2]Present address: eleQtron GmbH, Heeserstraße 5, 57072 Siegen

Important requirements for the realisation of robust quantum computing are long qubit coherence times as well as high gate fidelities both of which suffer from uncontrolled parameter fluctuations (noise). Thus, eliminating and mitigating noise constitutes one of the major challenges to scalability. In the case of trapped-ion quantum computing, ion traps with segmented electrodes are one approach to scale up the number of qubits. However, electric field fluctuations at these DC electrodes lead to a further source of noise. We are currently setting up a cryogenic quantum demonstrator that will include a cryogenic digital-to-analog converter (DAC) combined with a switching matrix to tackle this issue.

To evaluate the strategy of using optical switches, we have installed proof-of-principle optical switches in a room temperature experiment using the first two copies of a micro-structured 2D segmented ion trap with built-in micromagnets. We show results of measurements of coherence time and gate fidelities, and discuss the effects of remaining electric noise at the electrodes.

Q 67.8 Thu 17:00 Philo 2. OG

High-fidelity quantum information processing with trapped barium ions via addressed off-resonant interactions — •Tommaso Faorlin[1], Lorenz Panzl[1], Phoebe Grosser[1], Walter Joseph Hörmann[1], Juris Ulmanis[2], Thomas Feldker[2], Alexander Erhard[2], Giovanni Cerchiari[1,3], Rainer Blatt[1,2,4], and Thomas Monz[1,2] — [1]Universität Innsbruck, Technikerstraße 25/4, Innsbruck, 6020, Austria — [2]Alpine Quantum Technologies (AQT) GmbH, 6020, Innsbruck, 6020, Austria — [3]Naturwissenschaftlich-Technische Fakultät, Universität Siegen, Walter-Flex-Straße 3, 57068, Siegen, Germany — [4]Institute for Quantum Optics and Quantum Information (IQOQI), 6020, Innsbruck, Austria

The Hyperion experiment aims at pushing the boundaries of coherent trapped-ion control. Our focus lies on improving gate fidelities and minimizing state-preparation and readout errors, in a quantum register of barium ions. Building on state preparation at the 1e-4 level, state readout at the 1e-5 level and single-ion addressing cross-talk on the 1e-4 level, I present a novel gate scheme, leveraging ground-state qubits with radially-addressed Raman interactions using 532 nm light. The entangling gates are mediated through the perpendicular, axial motional modes, utilizing the field gradient of the employed laser fields. This novel approach promises the low cross-talk from radial addressing in combination with improved gate performance offered by axial-mode mediated gates.

Q 67.9 Thu 17:00 Philo 2. OG

Raman addressing system for light-shift gates on Qudits in trapped ion quantum computer — •Raphael Poloczek, Tim Gollerthan, Manuel John, Peter Tirler, Michael Meth, Keshav Pareek, Lukas Gerster, Lisa Parigger, Timo Spalek, and Martin Ringbauer — Institut für Experimentalphysik, Universität Innsbruck, Austria

Qudits, the generalization of qubits to d-level quantum systems, offer a powerful extension of conventional two-level quantum computing. Trapped ions represent a platform for realizing such systems, as their intrinsic multilevel structure naturally supports qudit encoding, providing access to higher-dimensional Hilbert spaces and enabling enriched computational capabilities. Fully exploiting qudit-based architectures requires the realization of efficient quantum gates for qudits. A recently demonstrated light-shift gate mechanism constitutes such an operation, creating genuine entanglement between two qudits, while matching the system's local dimension [1].

We are developing an experimental setup to implement this entangling gate on a quantum computer using trapped $^{40}Ca^+$ ions as information carriers. The setup is designed to address single ions using a pair of counterpropagating Raman beams, which generate the state dependent dipole force required to operate this gate.

[1] P. Hrmo et al., Nat Commun 14, 2242 (2023)

Q 67.10 Thu 17:00 Philo 2. OG

Double side-addressed, high-NA ion trap system leveraging barium towards fault-tolerant quantum computing — Lorenz Panzl[1], Tommaso Faorlin[1], •Phoebe Grosser[1], Rainer Blatt[1,2,3], Thomas Feldker[3], Alexander Erhard[3], Georg Jacob[3], Giovanni Cerchiari[1,4], and Thomas Monz[1,3] — [1]Universität Innsbruck, Technikerstraße 25/4, Innsbruck, 6020, Austria — [2]Institute for Quantum Optics and Quantum Information (IQOQI), 6020, Innsbruck, Austria — [3]Alpine Quantum Technologies (AQT) GmbH, 6020, Innsbruck, 6020, Austria — [4]Naturwissenschaftlich- Technische Fakultät, Universität Siegen, Walter-Flex-Straße 3, 57068, Siegen, Germany

We present a high-performance quantum information processing unit based on trapped atomic ions that is designed to push current limits of gate fidelities and SPAM errors to the 10^{-4} level and below. We utilise barium ions in our experiment due to the long lifetime of the metastable D5/2 state (leading to high readout fidelities) and the availability of hyperfine structure, providing access to the ground-state clock qubit. We demonstrate state preparation fidelity at the 10^{-4} level and high detection efficiencies. We combine off-resonant, addressed optical pulses and global microwave pulses to perform addressed single-qubit rotations, and demonstrate a novel procedure for implementing a two-qubit geometric phase gate that utilises a transverse gradient to coherently excite the axial modes. In doing so, our experiment is independent of any sub-Hz optical phase stability requirements, as it is outsourced to the RF control.

Q 67.11 Thu 17:00 Philo 2. OG

A Cryogenic Tweezer-Array Platform for Entangling Ytterbium-171 Nuclear Spins via the Optical Clock Transition — •Mohammad Soltani[1], Julian Feiler[1,2], Konrad Koenigsmann[3], Jin Yang[3], Max Hachmann[1,2], and Peter Schauss[1,2,3] — [1]Institute for Quantum Physics, University of Hamburg, Hamburg, Germany — [2]The Hamburg Centre for Ultrafast Imaging, Hamburg, Germany — [3]Department of Physics, University of Virginia, Charlottesville, USA

Neutral atom platforms based on ytterbium have emerged as a promising architecture for quantum computing, particularly in scalable optical tweezer arrays that enable individual trapping and control of atoms. Specifically, the fermionic isotope Yb-171, with its nuclear spin of I = 1/2, provides a robust and natural qubit implementation.

In our project, we aim at realizing large-scale robust entanglement in the nuclear spin of ytterbium atoms trapped in a tweezer array with a cryogenic shield. For our entanglement scheme, we plan to rely on spin-exchange in combination with coherent driving of the clock transition. Therefore, we need a highly stable laser system to address the clock transition in Yb-171.

We will report on the progress in setting up the experiment and on our efforts to stabilize the clock laser to an ultra-stable reference cavity. To characterize the stability and accuracy of the laser system, we are preparing a comparison to other clock lasers at the Institute for Quantum Physics in Hamburg.

Q 67.12 Thu 17:00 Philo 2. OG

Integrated Quantum Information Processing with Novel Photonic Interfaces — •Louis L. Hohmann[1,2], Jeldrik Huster[1,2], and Stefanie Barz[1,2] — [1]Institute for Functional Matter and Quantum Technologies, University of Stuttgart, 70569 Stuttgart, Germany — [2]Center for Integrated Quantum Science and Technology (IQST)

Integrated quantum photonics has achieved significant progress in quantum computing, providing low-loss connections, a compact size, and high phase stability. These features enable reliable and space-efficient control of photonic qubits. Multipartite entangled states, such as GHZ and linear cluster states, are particularly important for quantum photonics as they serve as essential resource states for photonic quantum computing. We demonstrate our advancements in generating multipartite entangled states on a silicon-on-insulator photonic quantum circuit powered by spontaneous parametric down-conversion single-photon sources. The fiber-to-chip interface employs 3D-printed photonic wirebonds, a new, highly stable connection method between single-mode fibers and on-chip edge couplers, enabling a fully integrated quantum photonic circuit.

Q 67.13 Thu 17:00 Philo 2. OG

Faster, more efficient loading of Yb^+ and Ba^+ ions for mixed-species cryogenic trapped ion quantum computers — •Marwan Mohammed[1,2], Michael Johanning[2], and Christof Wunderlich[1] — [1]Department of Physics, School of Science and Technology, University of Siegen, 57068 Siegen, Germany — [2]eleQtron GmbH, 57072 Siegen, Germany

Trapped ion quantum computers (TIQCs) in cryogenic vacuum facilitate both longer lifetimes and reduced motional heating of Coulomb crystals. However, keeping a low heat load typically necessitates pulsed laser ablation for ion loading. Only a small fraction of slow-moving ablated atoms are trappable by surface trap chips, but capturing faster-moving ablated atoms by increasing trap depth would increase the laser cooling time and therefore loading time significantly, whereas using higher pulse fluences to trap more ions risks chip contamination.

To this end, we present improvements to the ion loading process for two cryogenic quantum demonstrators that utilise Yb^+–Ba^+ mixed crystals. Two-photon photoionisation schemes shall use autoionizing transitions with larger absorption cross-sections; we will investigate a 531 nm transition for Ba^+ and use autoionization spectroscopy to discover and characterise suitable Yb^+ transitions. In addition, we realise a fiber-coupled pulsed ablation laser for more consistent shot-to-shot loading, and investigate a loading scheme using a compact effusive atomic source. Overall, this will yield faster, more efficient ion loading, benefitting both TIQCs of larger ion numbers and trapping of low-abundance ionic species.

Q 67.14 Thu 17:00 Philo 2. OG

A cryo-compatible optical system for addressing and achromatic imaging of trapped Yb^+ and Ba^+ ions — •Ernst Alfred Hackler, Daniel Busch, Kunal Kumbhar, Marwan Mohammed, Patrick H. Huber, Dorna Niroomand, and Christof Wunderlich — Walter-Flex-Straße 3, 57072 Siegen

To interface with the ions in a cryogenic ion trap quantum computer, we need to guide different laser wavelengths to trapped ions inside a cryogenic vacuum chamber and image the ions precisely and with high collection efficiencies.

Firstly, we have simulated and constructed a modular, compact overlapping unit comprising dichroic mirrors in order to produce a combined, collimated laser beam containing all the necessary wavelengths for state detection and preparation of Yb^+ and Ba^+ ions. By using off-the-shelf parts and an optimization algorithm for determining the optimal mirror choice, we achieve overlapping of 8 wavelengths used for Yb^+ and Ba^+ from 369–935 nm. The laser intensities are well-above the saturation intensities of the ions at the position of a 10-ion chain. Secondly, we developed and built a system for simultaneous imaging of both ion species, without chromaticity errors. A reflective objective lens, originally designed at Leibniz Universität Hannover, allows for in-vacuum, achromatic fluorescence imaging closer to the ions' position, increasing the light collection efficiency. We were able to image components inside the cryostat and demonstrate the system's general behaviour.

Q 67.15 Thu 17:00 Philo 2. OG

Programmable Quantum Computers and Teleportation: Theory and Experiment — Hans-Otto Carmesin[1,2,3] and •Jannes Ruder[3] — [1]Universität Bremen, Fachbereich 1, Postfach 330440, 28334 Bremen — [2]Studienseminar Stade, Bahnhofstr. 5, 21682 Stade — [3]Gymnasium Athenaeum, Harsefelder Straße 40, 21680 Stade

We developed a quantum computer - demonstrator that can also work with laser light and that provides a universal set of quantum gates. It performs the operations of the gates with single photons or with coherent laser light. The quantum computer - demonstrator can be programmed by an electrooptical piezo based energy efficient polarizer POLARITE III, that is controlled by a Raspberry Pi 5. With it Qubits und optical quantum gates are controlled. Moreover, the quantum computer - demonstrator can illustrate the process of quantum teleportation, the transfer of a state of a qubit C to a qubit B via an entangled qubit A. This process represents a safe transfer of quantum information.

Q 67.16 Thu 17:00 Philo 2. OG

Utilizing TWA simulations as quantum inspired approximative solve for max-cut problems — •Dennis Breu[1], Tom Schlegel[1], Alexey Bochkarev[2], Simon Ohler[1], Michael Fleischhauer[1], and Maximilian Kiefer-Emmanouilidis[3] — [1]Department of Physics and Research Center OPTIMAS, RPTU-University of Kaiserslautern-Landau, D-67663 Kaiserslautern, Germany — [2]Department of Mathematics, RPTU Kaiserslautern-Landau — [3]DFKI Kaiserslautern and RPTU Kaiserslautern-Landau

There is still a big need to find classical algorithms to efficiently approximately solve NP-Hard problems, since near-term quantum computers are not up for the task yet. For the Max-Cut, a prototypical NP-Hard problem, we propose a method that models a Quantum Annealing (QA) protocol on a classical computer using the truncated Wigner approximation (TWA), achieving a runtime virtually competitive with existing solvers. The TWA is a semiclassical approximation that is able to take lowest order quantum-fluctuations into account. In the TWA simulation of Quantum Annealing quantum fluctuations are included through Monte-Carlo sampling of the initial state. The time evolution of these initial states is however described by ODEs only, which can easily be vectorized and accelerated through the use of GPUs. Moreover, our numerical experiments suggest that the number of trajectories required to model close-to-adiabatic schedules is relatively low. This fact, along with massive parallelization ability, allows us to outperform quantum computers available to us and get close to state of the art classical algorithms in terms of speed and accuracy.

Q 67.17 Thu 17:00 Philo 2. OG

Quantum Routing in Quantum Networks — •Johanna Seitz, Lukas Pausch, and Matthias Zimmermann — Deutsches Zentrum für Luft- und Raumfahrt e.V. (DLR), Institute of Quantum Technologies, Ulm, Germany

In the development of future quantum networks [1], investigating possible quantum-network applications beyond quantum key distribution protocols becomes more and more relevant, promising higher security over classical networks by communicating quantum information. Due to the no-cloning theorem, there is no direct quantum analogue to the classical network protocol of sending identical, unknown information to two receiving parties by creating copies before distribution. To overcome this, we develop a quantum routing scheme that takes an input state and sends partial information via superposition to two receiving parties (compare to: [2]). In this protocol, the amount of information distributed to each party is defined via an additional control qubit that is processed together with the input state. Furthermore, we analyze the reverse operation of quantum decoupling to recover the initial quantum state, which can be realized by non-deterministic operations. Research on quantum routing protocols like this could open up new applications for communication with quantum networks, going beyond the capabilities of current classical communication networks.

[1] S. Wehner, D. Elkouss, R. Hanson, Science **362**, eaam9288 (2018).

[2] B.K. Behera, T. Reza, A. Gupta et al., Quantum Inf. Process. **18**, 328 (2019).

Q 67.18 Thu 17:00 Philo 2. OG

Recent advances in the implementation of a post-processing pipeline for a star-shaped quantum key hub — •Tobias Liebmann and Thomas Walther — TU Darmstadt, Institute of Applied Physics, 64289 Darmstadt

Quantum computing threatens the security of widely used public-key cryptographic schemes such as the Rivest-Shamir-Adleman (RSA) protocol. As a countermeasure, quantum key distribution (QKD) enables the generation of symmetric keys with information-theoretic security, making it suitable for one-time-pad encryption. However, distilling secure keys from raw quantum measurement data requires a complex classical post-processing pipeline. We present recent advances in the post-processing system of our QKD network, with a focus on error correction, authentication, and privacy amplification. In particular, we employ protograph-based LDPC codes for error correction, allowing the code length and rate to be adapted to different links in our network. For authentication of the classical channel we use a Wegman-Carter scheme, and Toeplitz hashing for privacy amplification. We analyze these components with respect to common performance metrics and benchmark them against our previous implementations as well as other published approaches.

Q 67.19 Thu 17:00 Philo 2. OG

Implementation of unidirectional modulation of polarization squeezed states for an experimental free-space continuous-variable quantum key distribution scheme — •Jan Schreck[1,2], Kevin Jaksch[1,2], Thomas Dirmeier[1,2], Hüseyin Vural[1,2], and Christoph Marquardt[2,1] — [1]Max Planck Institute for the Science of Light, Staudtstr. 2, Erlangen, Germany — [2]Chair of Optical Quantum Technologies, Friedrich-Alexander-Universität Erlangen-Nürnberg, Staudtstr. 7 / A3, Erlangen

Continuous-variable quantum key distribution (CV-QKD) provides a pathway toward quantum-safe cryptography. Polarization is a promising degree of freedom for encoding QKD signals in free-space optical (FSO) channels. In this context, the unidirectional modulation of polarization-squeezed states of light constitutes an experimental CV-QKD scheme that may enhance robustness against channel noise and limitations in post-processing efficiency. In this work, we present our approach to generating squeezed states of light as the source of quantum signals, and describe the corresponding sender and receiver setups for information transfer. Experimental characterization of the encoding concept based on electro-optical modulation is reported, indicating the feasibility of QKD with our implementation.

Q 67.20 Thu 17:00 Philo 2. OG

Phase Measurements in a Highly Imbalanced Interferometer — •Maximilian Mengler, Sarah Wenk, and Thomas Walther — TU Darmstadt, Darmstadt, Germany

In entanglement-based quantum key distribution using phase-time coding, entangled photon pairs can be generated by passing a double pulse through a nonlinear crystal. To achieve consistently low error rates, the phase between these pulses must be stabilized, and their timing must be precise. This can be achieved utilizing a highly imbalanced interferometer that splits one incoming pulse into two outgoing ones. In a first step, such an interferometer is commonly stabilized in its temperature, as shifts therein change the interferometer's phase. To further reduce instabilities, an active stabilization utilizing phase measurements can be used. As a first step, we introduce a scheme that allows the measurement of the interferometer's phase without altering the pulses that run through it, but by referencing them to an external signal.

Q 67.21 Thu 17:00 Philo 2. OG

Floquet engineering in a dissipatively protected subspace — •Liz Burton and Francesco Petiziol — TU Berlin, Hardenbergstraße 36, Berlin

A possible approach to quantum error correction is to encode information in the degenerate ground state of a gapped physical system, where correctable errors correspond to excitations of the system and are thus energetically penalized. Error correction is realized "passively", without active manipulation of the system, through dissipation processes that relax the system to the ground state. In our work, we consider a physical realization of the three-qubit code as an Ising model coupled to a bath that implements the necessary dissipative channels. We investigate how to realize logical operations in the code space by means of Floquet engineering techniques. Moreover, one of our major goals is to shed light on the interplay between the Floquet scheme and dissipative protection, and how it impacts the efficiency of the quantum error correction code.

Q 67.22 Thu 17:00 Philo 2. OG

Quantum Kolmogorov-Arnold Networks for Interpretable Healthcare Models — •Vanessa Stein[1], Yannick Werner[1,2], Akash Malemath[1], Nikolaos Palaiodimopoulos[1,2], Paula Manso Zorilla[2], Hamraz Javaheri[2], Mengxi Liu[2], Paul Lukowicz[1,2], Vitor Fortes Rey[1,2], Gregor Alexander Stavrou[3], Omid Ghamarnejad[3], and Maximilian Kiefer-Emmanouilidis[1,2] — [1]RPTU Kaiserslautern-Landau — [2]DFKI Kaiserslautern — [3]Department of General, Visceral and Oncological Surgery, Klinikum Saarbrücken

Transparency remains a major challenge in applying machine learning to healthcare, where understanding model decisions is crucial for clinical trust and adoption. Kolmogorov-Arnold networks provide a structurally interpretable alternative to conventional neural architectures by placing learnable functions on edges rather than nodes. We explore quantum realizations of these architectures using Quantum Circuit Born Machines to create compact, expressive models with directly accessible functional components. Initial results indicate that the approach enables interpretable decision pathways without sacrificing predictive performance compared to established classical and quantum classifiers. This highlights the potential of quantum machine learning to support trustworthy AI in healthcare by combining strong performance with enhanced interpretability.

Q 67.23 Thu 17:00 Philo 2. OG

Evaluating the Impact of Expert-Curated vs. LLM-Generated Feedback on Novice Quantum Programmer Performance — •Lars Krupp[1,2], Jonas Bley[2], Smriti Sharma[1,2], Maximilian Kiefer-Emmanouilidis[1,2], Paul Lukowicz[1,2], and Jakob Karolus[1,2] — [1]DFKI Kaiserslautern — [2]RPTU Kaiserslautern-Landau

The field of quantum computing (QC) faces a significant barrier to adoption due to the shortage of qualified educators. While online resources provide foundational knowledge, students often encounter coding challenges where a lack of timely, personalized assistance can severely stifle their learning progress. We present a user study on the PennyLane website using a plugin to inject different types of assistance into their error messages and investigate the efficacy of these assistance mechanisms for introductory QC coding tasks. Our study compares three types of assistance provided when a student's code fails: standard error messages, expert-curated messages, and personalized, Large Language Model (LLM)-generated support. Unlike the non-personalized expert messages, the LLM-based system reads and interprets the student's code and provides targeted guidance aimed at successful task completion. Learning gain is evaluated using a pre- and post-test design to assess the impact of these distinct support modalities on student understanding.

Q 67.24 Thu 17:00 Philo 2. OG

Synthetic Data Generation for Healthcare Prediction — •Paula Manso Zorilla[1], Yannick Werner[1,2], Hamraz Javaheri[1,2], Gregor Alexander Stavrou[3], Omid Ghamarnejad[3], Paul Lukowicz[1,2], Maximilian Kiefer-Emmanouilidis[1,2], and Vitor Fortes Rey[1,2] — [1]DFKI Kaiserslautern — [2]RPTU Kaiserslautern-Landau — [3]Department of General, Visceral and Oncological Surgery, Klinikum Saarbrücken

Advancing machine learning in healthcare is often hindered by limited, imbalanced, and privacy-sensitive clinical datasets. To address these constraints, we investigate physics-inspired synthetic data generation using GANs, large language models, and a Quantum Circuit Born Machine trained with maximum mean discrepancy loss. We assess the resulting datasets in terms of fidelity, privacy preservation, and practical utility by training classical and quantum classifiers while evaluating performance exclusively on real patient data. Our findings show that synthetic clinical data can improve robustness and predictive capability in low-data settings. This demonstrates how quantum and classical generative models can help unlock reliable, privacy-preserving AI for real-world healthcare applications.

Q 67.25 Thu 17:00 Philo 2. OG

Quantum-Inspired Low-Entanglement Optimization Techniques for Image Segmentation — •Marie Gogolin[1], Richard Castro[1,2], Yannick Werner[1,3], Ali Mogisheh[2], Alexander Geng[2], Arcesio Castaneda Medina[2], Paul Lukowicz[1,3], and Maximilian Kiefer-Emmanouilidis[1,3] — [1]RPTU Kaiserslautern-Landau — [2]Fraunhofer ITWM Kaiserslautern — [3]DFKI Kaiserslautern

Optimization problems such as image segmentation can be mapped to ground-state computations in Ising-type models, allowing quantum and quantum-inspired methods to be applied to real-world tasks. In this work, we investigate a spectrum of approaches to solving such problems, starting from the Max-Cut formulation and comparing exact diagonalization, imaginary-time evolution, and quantum annealing techniques. The focus lies on tensor-network methods. Matrix Product States and Projected Entangled Pair States, which enable scalable simulations of one- and two-dimensional systems with controllable entanglement. We further integrate quantum annealing concepts with tensor-network optimization by combining generalized PEPS using the simple-update scheme with a Floquet-based adiabatic evolution approximation. Numerical experiments on image segmentation benchmark the strengths and limitations of these techniques across varying system sizes and problem structures. The results demonstrate the potential of low-entanglement tensor networks as powerful tools for quantum-inspired optimization, bridging theoretical developments with practical applications in computer vision.

Q 67.26 Thu 17:00 Philo 2. OG

First-detection return statistics in quantum walks with long-range hopping — •Sayan Roy[1], Shamik Gupta[2], Giovanna Morigi[1], and Gabriele Perfetto[3] — [1]Theoretische Physik, Universität des Saarlandes, D-66123 Saarbrücken, Germany — [2]Department of Theoretical Physics, Tata Institute of Fundamental Research, 1 Homi Bhabha Road, Mumbai, 400005, India — [3]Institut für Theoretische Physik, ETH Zürich, Wolfgang-Pauli-Str. 27, 8093 Zürich, Switzerland

Quantum walks are paradigms for many-body dynamics and are analog realization of quantum algorithms such as the quantum search. Key characterizing concepts are quantum recurrence, which describes the ability of a quantum walker to return to its initial state, and the associated first-detection time, which is the time interval elapsed between the initial time and the recurrence. In this work, we analyze a quantum walk on a chain with long-range hopping , where the coupling between sites at distance d decays as $d^{-\alpha}$, with $\alpha \geq 0$. The walker evolves unitarily between stroboscopic projective measurements on the initial site performed at times $t_n = n\tau, n \in \mathbb{N}$. Our study shows that the nature of the walk is controlled by the hopping exponent α. In the strong long-range regime $\alpha < 1$, interference tends to localize the walker and the quantum walks are recurrent: the walker returns to the origin with probability one. For $\alpha > 1$, instead, the first-detection probability decays algebraically, with exponent depending on α, leading to a transient quantum walk. We connect these behaviors with the spectral features of the model.

Q 67.27 Thu 17:00 Philo 2. OG

Non-Exponential Decay in Finite Photonic Waveguide Arrays — •Florian Huber[1,2,3,4], Benedikt Braumandl[1,2,3,5], Johannes Knörzer[6], Jonas Himmel[7], Carlotta Versmold[1,2,3], Robert Jonsson[8], Alexander Szameit[7], and Jasmin Meinecke[1,2,3,4] — [1]Ludwig-Maximilians-Universität München — [2]Max-Planck Institut für Quantenoptik — [3]Munich Center for Quantum Science and Technology (MCQST) — [4]Technische Universität Berlin — [5]Technische Universität München — [6]ETH Zurich — [7]Universität Rostock — [8]Malmö University

Tight-binding models with a single defect at the edge of a lattice give rise to a variety of dynamical behaviors and provide a well controlled minimal setting to study decay in open quantum systems. Transitioning between exponential decay, non-exponential relaxation or oscillatory dynamics is possible by only varying a single parameter. To explore these effects experimentally, we use fused silica waveguide arrays providing a versatile yet well controllable platform and a natural realization of tight-binding models with varying coupling strengths and boundary conditions. To analyze the suitability of the experimental platform we characterize the waveguide arrays in detail and use the reconstructed refractive index profile for additional numerical eigenmode-expansion simulations. By comparing the analytic solution to our experimental data and additional numerical simulations and by taking finite-size effects into account we establish a general framework and benchmark for assessing how waveguide-based quantum simulator implementations can reliably emulate infinite or semi-infinite models.

Q 67.28 Thu 17:00 Philo 2. OG

Quantum searches as quantum walks on a graph with variable connectivity — •Giovanni Ragazzi[1], Emma King[2], Paolo Bordone[1], Giovanna Morigi[2,3], Matteo Paris[4], and Andrea Solfanelli[5] — [1]Dipartimento di Scienze Fisiche, Informatiche e Matematiche, Università di Modena e Reggio Emilia, I-41125 Modena, Italy — [2]Theoretische Physik, Universität des Saarlandes, D-66123 Saarbrücken, Germany — [3]Center for Quantum Technologies (QuTe), Saarland University, Campus, 66123 Saarbruecken, Germany — [4]Dipartimento di Fisica Aldo Pontremoli, Università di Milano, I-20133 Milano, Italy — [5]Max Planck Institute for the Physics of Complex Systems, Nöthnitzer Str. 38, 01187 Dresden, Germany

A quantum walk on a lattice is a paradigm of a quantum search in a database. For quantum walks on a continuous time, the walker diffuses across the lattice and the search ends when it localizes at the target site. The search time T can exhibit Grover's optimal scaling with the lattice size N, namely, $T \sim \sqrt{N}$, on an all-connected, complete lattice. For finite-range tunneling between sites, instead, Grover's optimal scaling is warranted when the lattice is a hypercube of $d > 4$ dimensions. In a recent work, it was shown that Grover's optimum can be reached in lower dimensions on lattices of long-range interacting particles, when the interaction strength scales algebraically with the distance r as $1/r^{\alpha}$ and $0 < \alpha < 3d/2$. In this contribution, we extend the formalism to determine the computational time complexities of quantum walks on graph with different geometries, considering in particular sparse graphs and chiral effects.

Q 67.29 Thu 17:00 Philo 2. OG

Statistical properties of quantum ensembles on hyperspheres — •Max Tartler and Reinhold Walser — Institut für Angewandte Physik, TU Darmstadt, Hochschulstraße 4A, 64289, Darmstadt

Quantum states are described by density operators and carry the entire information of a physical system. The Bloch sphere provides a geometric representation of all possible quantum states for spin 1/2-systems [1]. The question arises how quantum systems of higher dimension, such as multipartite ones, can be understood geometrically.

In this contribution, we give a geometric representation of quantum states in arbitrary dimensions. The key to this approach is the Cholesky decomposition of positive definite matrices [2]. One finds that the entire Hilbert space of N dimensions can be mapped onto a sector of the real unit hypersphere in N^2 dimensions. We analyze where special classes of quantum states are located in this picture. Furthermore, the statistical properties of homogeneously distributed quantum states on the hypersphere are resolved through the computation of the probability distribution function of the density matrices.

[1] Quantum Computation and Quantum Information: 10th Anniversary Edition, Michael A. Nielsen, Isaac L. Chuang p. 105 (2010)
[2] Matrix Analysis, Roger A. Horn, Charles R. Johnson p. 441 (2013)

Q 67.30 Thu 17:00 Philo 2. OG

Quantum states on hyper-spheres — •Christian Schaub and Reinhold Walser — Institute for Applied Physics, TU Darmstadt, Germany

Quantum entanglement is a key resource in today's quantum technologies, making its reliable quantification fundamentally important. A powerful strategy for characterizing entanglement is to decompose a quantum state into its local building blocks and compare these components with the original state, naturally connecting to the underlying geometry of quantum states [1]. While the Schmidt decomposition provides a perfect factorization, it only applies to pure states.

In this contribution, decomposition-based methods are therefore introduced for the analysis of arbitrary mixed states, with the Cholesky decomposition as a central element. The Cholesky decomposition provides a unique and compact factorization of density matrices and serves as the foundation for a hyper-spherical representation, in which quantum states can be interpreted as points on the surface of a hypersphere. Within this framework, entanglement can be understood as the geodesic distance on the hyper-sphere between the original state and the nearest separable state on the submanifold. This distance is minimized to quantify entanglement, yielding a closer separable approximation than partial-trace-based factorizations.

[1] Ingemar Bengtsson et al. Geometry of Quantum States: An Introduction to Quantum Entanglement. 2nd ed. Cambridge University Press, 2017

Q 67.31 Thu 17:00 Philo 2. OG

Applications of Multi-Qubit Gates for Scalable Quantum Algorithms in Trapped-Ion Systems — Eoin Potts, Alexander Gresch, Soronzonbold Otgonbaatar, Marcel Seelbach, Dimitris Badounas und •Michael Fromm — eleQtron GmbH, Heeserstr. 5, 57072 Siegen, Germany

Multi-qubit entangling gates are a central resource for achieving scalable quantum algorithms, particularly in trapped-ion quantum computing platforms where long-range interactions and high-fidelity control are available. In particular, we examine the efficient layering of Givens rotations enabled by collective multi-qubit interactions. We further discuss Hamiltonian engineering techniques that leverage native multi-qubit gates to encode optimization problems directly into effective many-body interactions. Finally, we address strategies for scaling multi-qubit gates beyond a single register, including modular architectures and ion shuttling.

Q 68: Poster – Precision Measurement (joint session Q/A)

Matter Wave Optics and Interferometry; Atom and Ion Clocks; Nuclear Clocks; Metrology; Others

Time: Thursday 17:00–19:00 Location: Philo 2. OG

Q 68.1 Thu 17:00 Philo 2. OG

Optical simulations for noise analyses in space-based interferometers — •Rodrigo Garcia Alvarez — Max Planck institute for Gravitational Physics (Albert Einstein Institute), Hannover, Germany

A major contributor of noise in the Laser Interferometer Space Antenna (LISA) is the so-called tilt-to-length coupling (TTL). This is the path length signal noise induced by angular and lateral jitters in an interferometric setup. Various TTL noise simulations conducted using IfoCAD, an in-house interferometry c++ library are presented. These simulations include TTL noise in the test mass interferometers and the inter-satellite interferometers, caused by the jitter of the transmitting and receiving spacecraft. The status of IfoCAD simulations using LISA's latest optical design is included.

Q 68.2 Thu 17:00 Philo 2. OG

Unifying Sequential Bragg and Bloch Large-Momentum-Transfer Atom Interferometry — •Ashkan Alibabaei[1], Patrik Mönkeberg[2], Klemens Hammerer[2,3,4], and Naceur Gaaloul[1] — [1]Institut of Quantum Optics, Leibniz University Hannover, Germany — [2]Institute für Theoretical physics, Leibniz University Hannover, Germany — [3]Institute for Quantum Optics and Quantum Information of the Austrian Academy of Sciences, Innsbruck, Austria — [4]Institute for Theoretical Physics, University of Innsbruck, Innsbruck, Austria

Large-momentum-transfer (LMT) techniques significantly enhance the sensitivity of atom interferometers. Although Bloch oscillations and sequential Bragg diffraction are widely used, they are typically treated as separate methods. We introduce a unified Floquet framework that encompasses both processes within a single theoretical description, enabling direct and systematic comparison. Using this approach, we analyse losses and dephasing and establish criteria for achieving their fundamental performance limits. The framework is validated through agreement with exact numerical simulations and recent state-of-the-art experimental results [Rodzinka et al., Nat Commun 15, 10281 (2024)], providing a robust foundation for optimizing future LMT implementations.

Q 68.3 Thu 17:00 Philo 2. OG

Development of a Compact Electronic System for the Absolute Aero Quanten-Gravimetry (AeroQGrav) Project — •Patrick Rössler, Knut Stolzenberg, Ernst Rasel, and Dennis Schlippert — Leibniz Universität Hannover - Institut für Quantenoptik

To map the Earth's gravitational field within a restricted area we utilize an airplane as a platform for combining inertial and positional sensors at lower altitudes. Within a measuring duration of 5 s we are aiming for a spatial resolution of 0.3 to 0.5 km, by the implementation of a cold atom quantum gravimeter with the sensitivity of 1 μm/s^2 and combine it with the data stream of the GNSS position system, a terrestrial laser scanner and a laser velocity meter. The presented work shows the requirements to build a robust, fast and precise electronic system to operate the quantum gravimeter and merge the aforementioned sensors data streams using sensor fusion in the noisy environment of an airplane.

Q 68.4 Thu 17:00 Philo 2. OG

Double Bragg atom interferometry with Bose-Einstein condensates in microgravity — •Anurag Bhadane[1], Dorthe Leopoldt[2], Priyanka Barik[2], Govindarajan Prakash[3], Julia Pahl[4], Sven Herrmann[3], Andre Wenzlawski[1], Sven Abend[2], Markus Krutzik[4,5], Patrick Windpassinger[1], Ernst Rasel[2], and The Quantus Team[1,2,3,4,6,7] — [1]JGU Mainz — [2]LU Hannover — [3]ZARM, U Bremen — [4]HU Berlin — [5]FBH Berlin — [6]U Ulm — [7]TU Darmstadt

The Quantus-2 device is a mobile, high flux ^{87}Rb Bose-Einstein condensate(BEC) interferometer optimized for microgravity platforms such as the Bremen Drop Tower and the GraviTower Bremen Pro, and serves as a pathfinder for future space based quantum sensors. A magnetic quadrupole lens combined with collective mode excitation of the BEC enables interferometry times beyond one second using double Bragg diffraction. At these durations, systematic effects like parasitic wavefront distortions, which imprint spatial phase variations across the atomic cloud, together with shot to shot pulse amplitude fluctuations reduce the achievable contrast. We present the dominant contrast loss mechanisms, supported by quantitative performance characterization, and outline mitigation strategies for long duration interferometry in microgravity.

This project is supported by the German Space Agency DLR with funds provided by the Federal Ministry for Economic Affairs and Energy under grant numbers DLR 50WM1952-1957 and DLR 50 WM2450A-F.

Q 68.5 Thu 17:00 Philo 2. OG

Towards a quantum inertial measurement unit for navigation utilizing BEC based atom interferometry — •Tobias Bullwinkel, Mouine Abidi, Philipp Barbey, Ashwin Rajagopalan, Ann Sabu, Dennis Schlippert, Ernst M. Rasel, and Sven Abend — Leibniz Universität Hannover, Institut für Quantenoptik

Future enhanced inertial measurement units require more long-term stable and accurate sensors. Utilizing atom interferometry, sensors can be realized that offer drift-free performance and are not vulnerable to signal jamming, in contrast to current navigation solutions. By hybridizing conventional methods with newly developed quantum-sensors, the best of both worlds is combined. The QGyro project aims to create a sensor that is capable of doing three-axis measurements while hybridizing the measurements to a classical IMU. For this, atom iterferometry with Bose-Einstein condensates generated with the help of an atom chip is used. Since mobility is crucial for the system being used in navigation, development is done with transportability and resilience against external factors in mind. All of the sensor periphery is built for easy assembly and fits into one 19* rack, as the electronics and laser systems are designed to be as compact as possible. Additionally, it can be supplied by an external battery, enabling measurements campaigns without constant external power supply. The ARTIQ control system is utilized to run the experimental sequence with extreme accurate time control.This work is supported by the Federal Ministry of Economics and Climate Protection (BMWK) due to the enactment of the German Bundestag under Grant No. DLR 50NA2106 (QGyro+).

Q 68.6 Thu 17:00 Philo 2. OG

Challenges behind performing atom interferometry in extended free fall — •Priyanka Barik[1], Govindarajan Prakash[2], Dorthe Leopoldt[1], Anurag Bhadane[3], Julia Pahl[4], Sven Abend[1], Sven Herrmann[2], André Wenzlawski[3], Markus Krutzik[4,7], Patrick Windpassinger[3], Ernst M. Rasel[1], and QUANTUS Team[1,2,3,4,5,6,7] — [1]LU Hannover — [2]ZARM, U Bremen — [3]JGU Mainz — [4]HU Berlin — [5]U Ulm — [6]TU Darmstadt — [7]FBH Berlin

The QUANTUS-2 apparatus is a high-flux ^{87}Rb BEC machine, based on a magnetic chip-trap, which generates $1{\times}10^5$ atoms at a 1Hz rate. High-precision quantum sensing with atom interferometers requires long interrogation time of several seconds with ultra-low expansion rates of the BECs. Thus, we perform our experiment in the DropTower in Bremen with a novel matter-wave lens system for the collimation of the condensate. The apparatus experiences noticeable tilts and rotations which alter the spatial rotation of the ^{87}Rb atomic cloud and its projection along the imaging axes and the interferometry pulses. These rotations lead to position offsets, which become more pronounced as the TOF is increased, and, hence, are expected to contribute to a loss of contrast of the interferometer. We report on the proposal to mitigate these problems using a retro-reflective mirror mounted on a tip/tilt platform which will pave the way for long interrogation times. This project is supported by the German Space Agency DLR with funds provided by the Federal Ministry for Economic Affairs and Climate Action under grant numbers DLR 50WM1952-1957 & DLR 50WM2450A-F.

Q 68.7 Thu 17:00 Philo 2. OG

Improving PIXL — •Knut Stolzenberg, Daida Thomas, Christian Struckmann, Ashwin Rajagopalan, Alexander Herbst, Wei Liu, Konstantin Avvacumov, Sebastian Bode, Naceur Gaaloul, Ernst Rasel, and Dennis Schlippert — Institut für Quantenoptik, Leibniz Universität Hannover

Atom interferometers have become a viable tool for inertial sensing and fundamental research, showing excellent long-term stability and sensitivity. However, they are commonly bound to a single sensitive axis, enabling multi-axis inertial sensing only via post-correction with external classical sensors, or correlation with other simultaneous atom interferometers.

The PIXL (Parallelized atom Interferometers for XLerometry) method, utilizing a 3 x 3 array arrangement of Bose-Einstein condensates as input for Mach-Zehnder type atom interferometers, allows for the measurement of the Euler- and centrifugal acceleration, as well as transversal acting linear accelerations induced by gravity.

PIXL's optical dipole trap setup can furthermore accelerate the ensembles transversal to the atom optics light field, resulting in additional phase shifts in the atom interferometers due to the Sagnac effect. Here, first results of improved rotation sensing and post correction of obstructive vibrations are presented.

Moreover, we envision PIXL as a highly accurate tool to characterize wave front abberations, being the main limitation for e.g. the measurement of the fine structure constant.

Q 68.8 Thu 17:00 Philo 2. OG

Frequency ratio measurements at the 10^{-18} level with an aluminum ion clock — •Fabian Dawel[1,2], Derwell Drapier[1], Mirza Akbar Ali[1,2], Lennart Pelzer[1], Kai Dietze[1,2], Bennet Benny[1,2], Johannes Kramer[1,2], and Piet O. Schmidt[1,2] — [1]PTB, Braunschweig, Germany — [2]LUH, Hannover, Germany

The latest generation of optical atomic clocks claims two orders of magnitude improved statistical and systematic frequency uncertainty compared to microwave Cs-clocks. For the redefinition of the second confirmation of the estimated error budgets of optical clocks by frequency ratio measurements is required. Here, we present frequency ratio measurements of our Al^+ ion clock, which is co-trapped with Ca^+ for readout and cooling. The co-trapped ion allows sympathetic electromagnetically-induced transparency cooling during the clock interrogation, which reduces the second-order Doppler effect to a small and probe-time independent value. The introduced electric field of the cooling lasers can be characterized by Ca^+ allowing to bound the ac-Stark shift on Al^+ on a low 10^{-18} uncertainty level, which is the largest contribution to the total systematic frequency uncertainty of 1.7×10^{-18}. We show frequency ratio measurements against a Sr lattice clock with a stability of $5.9\times10^{-16}\sqrt{1\,\mathrm{s}/\tau}$, limited by the Al^+ ion clock stability. The resulting frequency ratio of $^{27}Al^+/^{87}Sr$ shows a $14\,\sigma$ difference to published results. This shows the importance of inter-institutional frequency ratio measurement for the redefinition of the second.

Q 68.9 Thu 17:00 Philo 2. OG

Advancements of a transportable quantum logic optical clock. — •Sofia Herbers[1], M. Mazin Amir[1,2], Alexander Bernet[1,2], Pascal Engelhardt[1,2], Joost Hinrichs[1,2], Constantin Nauk[1,2], Gayatri Sasidharan[1,2], and Piet O. Schmidt[1,2] — [1]Physikalisch-Technische Bundesanstalt, 38116 Braunschweig, Germany — [2]Leibniz Universität Hannover, 30167 Hannover, Germany

Research in the field of geodesy [1,2], fundamental physics [3], and large scale networks can be performed and complemented with optical clocks. Besides stationary systems, this research also requires transportable systems, which can be operated at different points of interest. We set up a transportable quantum logic optical clock based on $^{27}Al^+$ and $^{40}Ca^+$ and present our latest advancements. We optimized the loading process of a two-ion crystal by an automated two-step splitting protocol. Additionally, we set up a compact, single-pass, and frequency-stable fourth harmonic generation (FHG) to generate 267 nm light for driving the clock transition of $^{27}Al^+$, for which we demonstrated a fractional frequency instability below 5×10^{-17} for the phase-stable light transfer through the FHG at one second averaging time. Furthermore, we optimized our cooling protocol, and investigated magnetic field attenuation using a mu-metal shield. [1] T. E. Mehlstäubleret al. (2018), Rep. Prog. Phys. **81**, 064401 [2] Safronova et al. (2018), Rev. Mod. Phys., **90**, 025008 [3] Vincent et al. (2024), arXiv preprint arXiv:2411.07888

Q 68.10 Thu 17:00 Philo 2. OG

Miniaturized Rubidium Two-Photon Frequency Reference Utilizing MEMS Cells — •Daniel Emanuel Kohl[1,2], Julien Kluge[1,2], Moritz Eisebitt[1,2], Janice Wollenberg[1], Klaus Döringshoff[1,2], Sten Wenzel[1], Andreas Wicht[1], and Markus Krutzik[1,2] — [1]Ferdinand-Braun-Institut (FBH) — [2]Institut für Physik - Humboldt-Universität zu Berlin

Optical frequency references based on frequency modulation spectroscopy of atomic vapor are promising candidates for the realization of compact optical clocks with applications including optical calibration, synchronization and navigation. We present the development of a miniaturized rubidium two-photon frequency reference using FM spectroscopy of the $5S_{1/2}\rightarrow5D_{5/2}$ transition at 778.1 nm. The reference features a 72 ml ($67{\times}32.5{\times}33\,\mathrm{mm}^3$) spectroscopy unit utilizing microfabricated wafer-bonded rubidium vapor cells.

The spectroscopy unit is driven by a chip-scale ECDL laser as a 778.1 nm light source. We present a first demonstrator achieving short-term fractional frequency instability of $2.8\cdot10^{-12}/\sqrt{\tau}$ up to 200 s, with a flicker floor at $2\cdot10^{-13}$. These results show the potential of chip-scale rubidium two-photon frequency references. We aim to further miniaturize and integrate the laser system with a microfabricated-cell spectroscopy module to realize a scalable rubidium optical clock.

This work is supported by German Federal Ministry of Research, Technology and Space, under grant number 50WM2164 and within the Research Program Quantum Systems under contract number 13N17491.

Q 68.11 Thu 17:00 Philo 2. OG

Portable implementation of a Ramsey Bordé atom interferometer with a thermal strontium beam for compact optical clocks — •Amir Mahdian[1,2], Oliver Fartmann[1], Marc Christ[2], Levi Wihan[1], and Markus Krutzik[1,2] — [1]Humboldt-Universität, Inst. f. Physik, Newtonstr. 15, 12489 Berlin — [2]Ferdinand-Braun-Institut (FBH), Gustav-Kirchhoff-Straße 4, 12489 Berlin

Compact optical atomic clocks based on Ramsey Bordé interferometry (RBI) with thermal atomic beams promise higher stability than optical vapor-cell clocks at substantially reduced complexity compared to cold-atom systems. Building on our previous demonstration[1] on the narrow $^1S_0\rightarrow{}^3P_1$ line of strontium at 689 nm, and using the $^3P_1\rightarrow{}^3P_0$ at 483 nm as an alternative for electron shelving detection, we now report our progress towards a portable RBI clock package. The portable apparatus features an integrated thermal atomic source and vacuum system with an in-vacuum micro-integrated retroreflector, as well as a compact spectroscopy setup. We have performed spectroscopy on the 461 nm transition and implemented frequency-modulation spectroscopy with the portable hardware. We will present the latest status of our setup, including initial stability characterization, and the roadmap to full RBI operation and field deployment. These results outline a path to robust, mobile, and ultimately space-qualified optical frequency references based on thermal-beam interferometry.

[1] O. Fartmann et al., EPJ Quantum Technol. 12, 31 (2025).

Q 68.12 Thu 17:00 Philo 2. OG

Entanglement-enhanced multi 40Ca+ ion clock — •Bennet Benny[1,2], Kai Dietze[1,2], Lennart Pelzer[1,2], Vincent Barbé[1], Ludwig Krinner[1,2], Fabian Dawel[1,2], Derwell Drapier[1], Mirza A. Ali[1,2], and Piet O. Schmidt[1,2] — [1]QUEST, Physikalisch-Technische Bundesanstalt, 38116 Braunschweig, Germany — [2]Leibniz Universität Hannover, 30167 Hannover, Germany

State-of-the-art optical atomic clocks based on trapped ions require long interrogation times and ion numbers to achieve low statistical uncertainty, but both methods are limited by various noise sources. Therefore, a small number of entangled ions with Quantum Projection Noise (QPN) below Standard Quantum Limit (SQL) might be beneficial. We demonstrated entanglement gain leading to faster averaging and suppression of magnetic-field noise in 40Ca+ ions in Decoherence-Free Subspace (DFS)[1]. Entanglement also provides an improvement in the measurement uncertainty through a reduction in QPN. The DFS method demonstrated near-lifetime-limited interrogation, but any further gain is suppressed by spontaneous-emission events during interrogation. To address this, we propose an experimental implementation of an entanglement-assisted readout method that employs a 4-tone Mølmer-Sørensen gate based DFS to detect and veto spontaneous-emission events from the clock feedback loop. This approach is designed to demonstrate an enhancement beyond SQL and its scaling of the achievable lock performance with ion numbers[2].

[1] K. Dietze et al., arXiv:2506.11810 (2025)
[2] T. Kielinski et al., Sci. Adv. 10, eadr1439 (2024)

Q 68.13 Thu 17:00 Philo 2. OG

Frequency-Comb Induced Excitation of ^{229}Th in a Crystalline Environment — •Chiara Brüggemann, Tobias Kirschbaum, and Adriana Pálffy — Julius-Maximilians-Universität Würzburg

Large band gap crystals such as CaF_2 or $LiCaAlF_6$ serve as an ideal host for doping ^{229}Th. This procedure leads to the formation of additional electronic defect states in the band gap. Various works have shown that these states can be used to excite the nuclear ground state population via laser-assisted Electronic Bridge (EB) schemes [1-3]. The EB rate for the ^{229}Th isomeric transition can be calculated using a perturbative approach [3].
In this work, we theoretically investigate EB excitation assisted by optical frequency combs. The latter open new avenues for EB excitation mechanisms using two photon-schemes, as their discrete line spectrum provides ideal conditions for delivering resonant photon pairs. Our approach based on Ref. [3] includes realistic crystal lattice effects, in particular inhomogeneous broadening of the electronic defect states.

[1] B. Nickerson et al., Phys. Rev. Lett. 125, 032501 (2020)
[2] B. Nickerson et al. Phys. Rev. A 103, 053120 (2021)
[3] T. Kirschbaum et al. arXiv:2507.05070 (2025)

Q 68.14 Thu 17:00 Philo 2. OG

Tuning and preparation of a laser system for airborne atom interferometry — •Alisa Ukhanova[1], Julia Pahl[1], Markus Krutzik[1,2], and the AeroQGrav team[1,3,4,5,6,7,8,9] — [1]Humboldt-Universität zu Berlin, Institut für Physik — [2]Ferdinand-Braun-Institut (FBH), Leibniz-Institut für Höchstfrequenztechnik, Berlin — [3]LUH, Hannover — [4]DLR, Hannover — [5]TUB, Braunschweig — [6]BKG, Leipzig — [7]TUC, Clausthal — [8]Geo++®GmbH, Garbsen — [9]iMAR Navigation GmbH, Ingbert

The "AeroQGrav" project strives to demonstrate an airborne atomic gravimeter, with a higher spatial and temporal resolution and a better long-term stability compared to the existing commercial solutions.

We develop a compact and robust modular flight laser system. Three functional modules provide the light fields for laser cooling of ^{87}Rb atoms in 2D- and 3D-magneto-optical traps, Raman interferometry, and state detection during flight. This poster highlights the design, assembly and verification of the system, with an emphasis on frequency stabilization methods. Our laser system meets the requirements arising from aircraft operation.

Future work will focus on a detailed characterization of the laser system to validate its performance under flight conditions. This project is supported by the VDI Technologiezentrum GmbH with funds provided by the Federal Ministry of Education and Research (BMBF) under grant number 13N16518.

Q 68.15 Thu 17:00 Philo 2. OG

Quantum Systems With Multiple Weak Interactions — •Vinay Tumuluru[1,2,3], Jan Dziewior[1,2,3], Carlotta Versmold[1,2,3], Florian Huber[1,2,3], Lev Vaidman[4], and Harald Weinfurter[1,2,3] — [1]Faculty of Physics, Ludwig-Maximilians-University, Munich, Germany — [2]Max-Planck-Institute of Quantum Optics, Garching, Germany — [3]Munich Center for Quantum Science and Technology (MCQST), Munich, Germany — [4]Raymond and Beverly Sackler School of Physics and Astronomy, Tel-Aviv University, Israel

The 'quantum weak value' of a pre- and post-selected quantum system [1] weakly interacting with a 'pointer' describes the amplification of effects of the weak interaction [2]. These amplified effects can be observed experimentally in optical interferometers where pre- and post-selection can be finely controlled and performed on different DOFs.

With the path and polarisation DOFs of an optical Mach Zehnder interferometer serving as two systems and the transverse mode of the beam serving as pointer, one can observe weak amplification in individual weak coupling of each system to the pointer as well as the product of amplifications when both systems are coupled simultaneously [3]. Here we analyse and show in the experiment how entanglement between the DOFs changes the resulting amplification significantly.

[1] Y. Aharonov et al, PRL. 60, 1351 (1988) [2] P. B. Dixon et al, Phys. Rev. Lett. 102 (2009) [3] X. Xu et al, PRL. 122, 100405 (2019)

Q 69: Collective Effects and Disordered Systems

Time: Friday 11:00–12:45 Location: P 2

Q 69.1 Fri 11:00 P 2

Spontaneous symmetry breaking in nonlinear superradiance — •Nikolai Klimkin[1] and Mikhail Ivanov[1,2,3] — [1]Max Born Institute, Max-Born Straße 2A, 12489 Berlin, Germany — [2]Institute of Physics, Humboldt University Berlin, 12489 Berlin, Germany — [3]Technion - Israel Institute of Technology, 3200003 Haifa, Israel

Creation and manipulation of non-classical states of light is rapidly becoming the focus of modern attosecond science. Here, we demonstrate numerically how such states can arise by considering a modification of the well-known problem of superradiance encountered already by Dicke. Similarly to him, we investigate photon emission by ensembles of indistinguishable atoms. In contrast to him, however, we leverage symmetry-based selection rules to suppress emission of single photons by single atoms. A steady state is therefore only reached following a spontaneous transition into a collective symmetry-broken state of atoms and photonic modes. The novel non-Markovian, non-perturbative method applied allows us to observe a large quantum state of light form and exhibit drastically non-classical statistics once the system undergoes a symmetry-breaking transition.

Q 69.2 Fri 11:15 P 2

Transport properties of fermionic excitations in a disordered toric code — •Luis Steinfadt and Francesco Petiziol — Technische Universität Berlin, Institut für Physik und Astronomie, Hardenbergstraße 36, Berlin 10623, Germany

A defining property of topologically ordered phases of matter is their long range entanglement, which enables the encoding of quantum information in non-local degrees of freedom. The resulting robustness against local perturbations establishes two-dimensional topological ordered systems as a promising physical hardware for quantum information processing.

However, any infinitesimal perturbation will delocalize thermally created excitations, a mechanism known to hinder the stability of quantum memories based on 2D topological order at any non-zero temperature. Thus, understanding the dynamics and transport properties of topological excitations in disordered topologically ordered systems poses a compelling question. On the one hand, it is crucial in quantifying the survival of the information encoded in the topologically degenerate ground states when subjected to (in-)coherent perturbations. On the other hand, it offers an opportunity to study the influence of exotic quantum statistics on (many-body) localization.

Motivated by this, we investigate the behavior of fermionic excitations in a disordered and perturbed toric code model and characterize their localization regimes. Based on these results, we further aim at exploring opportunities for controlling anyon motion in quantum simulations of topological order.

Q 69.3 Fri 11:30 P 2

Collective effects in cooling of ion crystals — •Ivan Vybornyi[1] and Klemens Hammerer[1,2] — [1]Leibniz Universität Hannover — [2]University of Innsbruck

Crystals of cold trapped ions are proven to be an outstanding platform to study controlled many-body physics and push the boundaries of quantum metrology. For this, careful entropy management is an essential prerequisite and laser cooling is routinely used to prepare the necessary low entropy mechanical motional states. However, with ion crystals increasing in size, the role of many-body effects in laser cooling has been largely overlooked and the possibility of collective enhancement remains unclear. In this work, we study a minimal theoretical many-body model for cooling arbitrary motional modes of an ion crystal and analyze the cooling behavior as more ions are added to the crystal. We identify regimes where the collective enhancement can provide a substantial boost to the cooling efficiency and discuss its advantages as well as limitations.

Q 69.4 Fri 11:45 P 2

Motion-induced unidirectionality of collective emission in a non-chiral waveguide — •Yoan Spahn[1], Benedikt Saalfrank[1], Jens Hartmann[2], Michael Fleischhauer[2], Thomas Halfmann[1], and Thorsten Peters[1] — [1]Institut für angewandte Physik TU Darmstadt — [2]Theoretical Quantum Optics Group, RPTU Kaiserslautern

We report the first observation of motion-induced unidirectionality in the collective emission of atoms confined within a hollow-core waveguide. Although the coupling of individual atoms to the guided radiation field is isotropic in forward and backward direction, we observe a pronounced directional suppression of superfluorescent burstsof up to 95% by tuning of the characteristic collective decay rate. Corroborated by numerical simulations based on the truncated Wigner approximation (TWA) and a simple model including location blur, we show that this behaviour arises because the decay occurs via a Raman-process-based effective two-level system with a spatially-dependent phase of the transition dipole moment. Furthermore, we study the two-time, second-order correlation function of the emitted light close to and well above the threshold to collective emission, showing a buildup of coherence during the superfluorescent bursts while the emitted light below the threshold exhibits thermal statistics.

Q 69.5 Fri 12:00 P 2

Long-range dipolar interactions in dilute, thermal alkali gases — Friedemann Landmesser, Vyacheslav Shatokhin, Ulrich Bangert, Frank Stienkemeier, Andreas Buchleitner, and •Lukas Bruder — Institute of Physics, Hermann-Herder-Straße 3, 79104, niversity of Freiburg

Unraveling the weak long-range interactions in disordered systems is challenging due to the dominating inhomogeneous spectral broadening. We have developed a highly sensitive nonlinear spectroscopy method to solve this problem [1]. This method is applied to dilute thermal alkali vapors. In a combined experimental and theoretical approach, we find evidence that in these systems the retarded, long-range part of the dipole-dipole interaction has to be taken into account to properly describe the inter-atomic many-body interactions [2].

[1] L. Bruder et al., Phys. Chem. Chem. Phys. 21, 2276 (2019). [2] V. Shatokhin et al. arXiv:2508.11480 (2025).

Q 69.6 Fri 12:15 P 2

Symbolic Quantum-Trajectory Method for Multichannel Dicke Superradiance — Raphael Holzinger[4], •Nico Bassler[1,2], Julian Lyne[2,3], Susanne Yelin[4], and Claudiu Genes[1,2] — [1]TU Darmstadt, Institute for Applied Physics, Hochschulstrasse 4A, D-64289 Darmstadt, Germany — [2]Max Planck Institute for the Science of Light, Staudtstrass e 2, D-91058 Erlangen, Germany — [3]Department of Physics, Friedrich-Alexander Universität Erlangen-Nürnberg (FAU), Staudtstrasse 7, D-91058 Erlangen, Germany — [4]Department of Physics, Harvard University, Cambridge, Massachusetts 02138, USA

We develop and solve a Dicke superradiant model with two or more competing collective decay channels of tunable rates. Recent work analyzed stationary properties of multichannel Dicke superradiance using hydrodynamic mean-field approximations. We extend this with a symbolic quantum-trajectory method, providing a simple route to analytic solutions. For two channels, the behavior of the stationary ground-state distribution resembles a first-order phase transition at the point where the channel-rate ratio is equal to unity. For d competing channels, we obtain scaling laws for the superradiant peak time and intensity. These results unify and extend single-channel Dicke dynamics to multilevel emitters and provide a compact tool for cavity and waveguide experiments, where permutation-symmetric reservoirs engineer multiple collective decay paths.

Q 69.7 Fri 12:30 P 2

Fast and slow scrambling in many-body long-range interacting systems — •Francesco Mattiotti and Giovanna Morigi — Theoretische Physik, Universität des Saarlandes, D-66123 Saarbrücken, Germany

Information scrambling, and its intimate relation to quantum chaos, represents one of the frontiers of research in condensed matter and many-body physics. A system which deteriorates information exponentially in time is called a fast scrambler, and the associated scrambling rate has been regarded as a quantum analog of the Lyapunov exponent, which in classical chaotic systems dictates the rate at which two initially closed trajectories diverge in phase space. Few condensed matter systems scramble fast, and, to the best of our knowledge, none saturates the bound on the quantum Lyapunov exponent, with the exception of the Sachdev-Ye-Kitaev (SYK) model. Here we investigate scrambling in the presence of long-range interactions and as a function of the initial state. We study how the spectral gap induced by long-range interactions affects the scrambling velocity of the system, depending on whether the initial state evolves inside a single subspace or multiple ones.

Q 70: Quantum Optics and Control II

Time: Friday 11:00–13:00 Location: P 3

Invited Talk Q 70.1 Fri 11:00 P 3

Totally destructive many-body interference beyond bosons and fermions — •Gabriel Dufour and Andreas Buchleitner — Physikalisches Institut & EUCOR Center for Quantum Science and Quantum Computing, Albert-Ludwigs-Universität Freiburg

The suppression of coincidence events in the Hong-Ou-Mandel experiment is a striking example of totally destructive many-body interference of two bosons. Similar effects have been described for greater numbers of bosons or fermions in larger interferometers. Here, we describe suppressions of certain particle configurations at the output of a Fourier interferometer when the many-body state on input has a specific symmetry under particle exchange, which need not be bosonic or fermionic.

Q 70.2 Fri 11:30 P 3

How to Break Symmetries to Get Quantum Systems under Control — •Thomas Schulte-Herbrüggen[1], Emanuel

Malvetti[1], and Gunther Dirr[2] — [1]Technical University of Munich (TUM), School of Natural Sciences — [2]University of Würzburg, Institute of Mathematics

In quantum engineering one wants to know "what one can do" with a given controlled dynamical system when starting with given initial conditions. The degree to which such a system can be controlled (accessed), observed, tomogaphied, or Kalman-filtered is readily judged by symmetries. To wit, those symmetries shared by the dynamic generators and the observables or filters.

We give constructive guidelines how to break symmetries to bring quantum systems under control, or observation, or Kalman-filtering. They are part of an overarching frame for quantum systems theory. [For a tutorial overview, see Proc. IEEE-CDC **63** (2024), p5231-5247.]

Q 70.3 Fri 11:45 P 3

Nonlinear excitations in laser driven two level systems — •Deniz Adigüzel, Miriam Gerharz, and Jörg Evers — Max-Planck-Institut für Kernphysik, Heidelberg, Germany

The extreme narrow linewidths of Mössbauer nuclei transitions render precision spectroscopy possible but subsequently make it also very challenging to achieve nonlinear excitations. Recent experiments at X-ray free electron lasers allow one to access new excitation regimes. This makes the study of nonlinearly excited nuclear systems particularly relevant. The interaction in question is a laser driven two level system which can be studied by solving the Maxwell-Bloch equations coupled with the propagation equation. As this system consists of a coupled partial differential equation, the analytical solution is in general not always obtainable. To overcome this problem, we implemented the method of lines to investigate light propagation beyond low excitations numerically. Here we report on the nonlinear timeshifts in the minima of the coherently scattered light and transitions around population inversion. Subsequently a signature was proposed in order to quantify the degree of excitation.

Q 70.4 Fri 12:00 P 3

Enhancing Stimulated Raman Scattering Using Kerr Squeezing — •Nikolay Kalinin[1], Kilian Scheffter[1,2], Seungwon Moon[1], Hannah Gallop[3], Mehdi Alizadeh[3], Adrian F. Pegoraro[4], Hanieh Fattahi[1,2], Alexey V. Andrianov[5], Albert Stolow[3], Luis L. Sánchez-Soto[1,6,7], and Gerd Leuchs[1,2,3] — [1]Max Planck Institute for the Science of Light, Erlangen, Germany — [2]Physik Department, Friedrich-Alexander-Universität Erlangen-Nürnberg, Erlangen, Germany — [3]Department of Physics, University of Ottawa, Ottawa, Canada — [4]Metrology Research Centre, National Research Council Canada, Ottawa, Canada — [5]Nizhny Novgorod, Russia — [6]Departamento de Óptica, Facultad de Física, Universidad Complutense, Madrid, Spain — [7]Institute for Quantum Studies, Chapman University, Orange, CA, USA

Squeezed light states provide a way to improve signal-to-noise ratio (SNR) in various measurements when classical methods face a limit. In state-of-the-art stimulated Raman scattering (SRS) experiments, such a limit is photodamage of biological samples. Recently, several groups demonstrated SRS with nonclassical light, where a $\chi^{(2)}$ nonlinearity was employed to produce squeezing. In this work, we explore an alternative approach based on Kerr ($\chi^{(3)}$) nonlinearity to enhance SRS. Our setup is relatively simple and robust, while also providing a perfect spatial mode for the Raman interaction. By injecting Kerr-squeezed light at 1.5 μm as the pump for the SRS in quartz, we achieve 3.0 dB of SNR improvement, a value on par with other known results.

Q 70.5 Fri 12:15 P 3

Pulse Engineering via Projection of Response Functions at Infinite Nonlinear Order — •Lia Kley[1,2] and Ludwig Mathey[1,2,3] — [1]Zentrum für Optische Quantentechnologien, Universität Hamburg, 22761 Hamburg, Germany — [2]Institut für Quantenphysik, Universität Hamburg, 22761 Hamburg, Germany — [3]The Hamburg Centre for Ultrafast Imaging, 22761 Hamburg, Germany

High-fidelity control of quantum systems requires methods that are both flexible and practical. We introduce a new method for optimal control that iteratively refines control parameters by evaluating the response of the fidelity to the applied control operators. It aims to implement target operations reliably with high fidelity, while extending established optimal-control techniques by providing access to the parameter update without the need for hyperparameter tuning, enhancing both practicality and applicability. To illustrate its potential, we discuss its application to a multi-qubit gate optimization task, comparing the method to existing approaches and highlighting improvements in usability and convergence relative to conventional strategies.

Q 70.6 Fri 12:30 P 3

Towards coherent dipole-dipole coupling of molecular dimers — •Dinesh Reddy[1,2], Ashley Shin[1], Tim Hebenstreit[1,2], Siwei Luo[1,2], Mikhail Kalinin[3], Alexander Oshchepkov[3], Jan Renger[1], Tobias Utikal[1], Konstantin Amsharov[3], Vahid Sandoghdar[1,2], and Stephan Götzinger[1,2] — [1]Max Planck Institute for the Science of Light, Erlangen, Germany — [2]Department of Physics, Friedrich Alexander University Erlangen-Nuremberg, Erlangen, Germany — [3]Department of Organic Chemistry, Martin-Luther-University Halle-Wittenberg, Halle(Saale), Germany

Coherent coupling between two quantum emitters via their optical near-field gives rise to the formation of sub- and superradiant entangled states. It can be experimentally challenging to optically confirm such coupling, as it typically requires emitters to be separated by only a few nanometers. We adopt a bottom-up synthetic approach, leveraging precise molecular engineering to tune the inter-emitter distance using tailored organic linkers. Our study focuses on single-molecule spectroscopy of dibenzanthanthrene (DBATT) that has shown to have high quantum yield and lifetime-limited linewidths at cryogenic temperatures (<2.2K). By functionalizing DBATT with various linker groups, we construct isolated monomers with linkers as well as dimers. We utilize a tunable narrow-band CW laser to obtain near lifetime-limited fluorescence excitation spectra as well as emission spectra with high spectral resolution to distinguish the effects of chemical functionalization from strong coupling. Additionally, we report autocorrelation and inhomogeneous broadening of all DBATT species.

Q 70.7 Fri 12:45 P 3

Storing images in hot atomic vapors — •Denis Uhland and Ilja Gerhardt — light & matter group, Institute for Solid State Physics, Leibniz University Hannover

The ability to reliably store and retrieve photons lies at the heart of emerging quantum technologies. A suitable medium for the storage and retrieval of photons are hot atomic vapors, which offer a possible way for room-temperature optical quantum memories. Previous works have demonstrated the storage and retrieval on the single photon level [1] and of images from a laser illuminated mask [2] in hot atomic vapors via electromagnetically induces transparency (EIT). Here, we show coherently storage and retrieval of two-dimensional images by exploiting the memory capabilities of the hot atomic vapor. Such image-preserving quantum memories overcome the idealized single-modal treatment of a collective excitation in an atomic ensemble. This combines the quantum storage of light with the unique sensing properties of a hot atomic vapor cell.

[1] L. Esguerra et al., Phys. Rev. A (2023) 107, 042607 [2] M. Shuker et al., Phys. Rev. Lett. 100, 223601

Q 71: Cavity QED and QED II

Time: Friday 11:00–13:00 Location: P 4

Q 71.1 Fri 11:00 P 4

Hyperbolic Phonon Polaritons and Color Centers in hBN: a new platform for quantum optics — •Jiecheng Feng[1,2,3], Johannes Eberle[1], Sambuddha Chattopadhyay[1,4], Johannes Knörzer[1], Eugene Demler[1], and Atac Imamoglu[1] — [1]ETH Zurich, Zurich, Switzerland — [2]Max Planck Institute for the Structure and Dynamics of Matter, Hamburg, Germany — [3]RWTH Aachen University, Aachen, Germany — [4]Harvard University, Massachusetts, USA

Hyperbolic phonon polaritons (HPPs) in hexagonal boron nitride (hBN) confine mid-IR light to deeply subwavelength scales but are typically generated and probed with classical near-field tips, limiting quantum control. We link this platform with the rapidly developing field of hBN color centers, bright, photostable, atomically localized emitters, by developing a cavity-QED framework in which a single color center serves as a quantum source of HPPs. We quantify emitter-HPP coupling and analyze two routes: spontaneous phonon-sideband emission, which yields single-HPP events and becomes single-mode in ultrathin slabs; and stimulated Raman driving, which provides frequency selectivity, tunable conversion, and narrowband excitation that launches directional, ray-like HPPs over micrometers. We also propose a two-emitter correlation test applicable to both schemes. Together, these results point to a new direction for mid-IR light-matter experiments that unite strong coupling, spectral selectivity, and spatial reach within a single material system.

Q 71.2 Fri 11:15 P 4

Cavity-assisted defect removal in a small-scale toric code — •Junyi Zhang and Francesco Petiziol — Technische Universität Berlin

We design and investigate a dissipative defect-removal mechanism in a small scale toric code coupled to a leaky cavity. The model considered includes coherent perturbations that delocalize either electric or magnetic anyon pairs, producing superpositions of error configurations with respect to information encoded in the ground state. By combining analytical and numerical tools, we study how coherent anyon delocalization competes with cavity-assisted dissipation engineering in determining cooling efficiency and steady state behavior, for different coupling schemes. This analysis provides insights into the potential and fundamental limitations of cavity-assisted cooling as a passive error suppression pathway in a topologically ordered system.

Q 71.3 Fri 11:30 P 4

Towards x-ray quantum optics using periodically structured cavities — •Robert Horn and Jörg Evers — Max-Planck-Institut für Kernphysik, Heidelberg, Germany

Due to their narrow linewidth, Mössbauer nuclei, such as ^{57}Fe, have become an important platform for studying the nature of photons in the hard x-ray regime. These nuclei not only serve as potential nuclear clocks but also emerge as promising candidates for x-ray quantum dynamics. A typical environment for studying quantum optical effects in the linear x-ray regime is that of a thin-film cavity with embedded Mössbauer nuclei probed at grazing incidence. A recently developed ab initio approach using the electromagnetic Green's tensor provides a robust theoretical and numerically efficient framework for describing this setup.

In this project, we propose a modified setup that breaks the system's translational symmetry along the wave-propagation direction by introducing a periodic spacing of the nuclei. Our aim is to investigate the emergence of additional scattering channels and the correlations between them, as well as to compute the corresponding reflection and transmission spectra.

Q 71.4 Fri 11:45 P 4

Comparison and interference of Photoelectron Circular Dichroism of a chiral molecule induced directly or by Interatomic Coulombic Decay of an antenna atom — •Lara Marie Tomasch, Omar Jesus Franca Santiago, and Stefan Yoshi Buhmann — Institut für Physik, Universität Kassel, Heinrich-Plett-Straße 40, 34132 Kassel, Germany

We aim to examine the photoelectron circular dichroism of a chiral molecule via two different channels: First, the direct ionization of the molecule with circularly polarised light. This is a well-known effect [1]. Alternatively, a non-chiral atom can serve as an antenna atom. This donor atom is first excited by circularly polarised light, the energy is then transfered via resonant Interatomic Coulombic Decay to the chiral acceptor molecule. There is a noticeable change in the resulting signal, depending on which channel is responsible for the ionisation [2].

In an experiment with intermediate distances between atoms and molecules both of these ionization channels can contribute simultaneously. We hence want to focus on possible interference effects and compare this simultaneous coherent process to the two individual processes.

[1]: Ritchie, B., Theory of the angular distribution of photoelectrons ejected from optically active molecules and molecular negative ions. Phys. Rev. A 13, 1411 (1976)

[2]: Buhmann, S. Y. et al, Photoelectron Circular Dichroism of a Chiral Molecule Induced by Resonant Interatomic Coulombic Decay from an Antenna Atom. Phys. Rev. Letters 134, 253001 (2025)

Q 71.5 Fri 12:00 P 4

Control of photon number wave packets in a microcavity — •Luca Nimmesgern[1], Moritz Cygorek[2], Doris E. Reiter[2], and Vollrath Martin Axt[1] — [1]Universität Bayreuth, Germany — [2]CMT, TU Dortmund, Germany

In order to implement quantum information algorithms, it is necessary to be able to directly control the quantum state of the underlying physical platform. Light is promising candidate, offering fast transmission and low decoherence. However, its infinite degrees of freedom make it challenging to define an optimal method for encoding information in its quantum state.

While most research is concerned with low photon numbers, our efforts are focused on states including higher, but not macroscopically large photon numbers. In this regime, structures, called photon number wave packets, which are characterised by an oscillating mean and finite width, have been recently investigated [1]. In this contribution, we show how the dynamics of these structures can be understood. Further, we demonstrate how additional packets can be dynamically created [2]. The conceptual simplicity of this manipulation might indicate the packet structure to be a suitable base for novel ways of information encoding.

[1] L. Nimmesgern *et al.*, Phys. Rev. B **109**, 155436 (2024).

[2] L. Nimmesgern *et al.* (submitted), arXiv:2509.03083.

Q 71.6 Fri 12:15 P 4

Master Equation for a quantum gas of polarizable particles in Cavities — •Tom Schmit[1], Catalin-Mihai Halati[2], Tobias Donner[3], Giovanna Morigi[1], and Simon B. Jäger[4] — [1]Theoretische Physik, Universität des Saarlandes, 66123 Saarbrücken, Germany — [2]Max Planck Institute for the Physics of Complex Systems, Nöthnitzer Str. 38, 01187 Dresden, Germany — [3]Institute for Quantum Electronics, Eidgenössische Technische Hochschule Zürich, Otto-Stern-Weg 1, 8093 Zurich, Switzerland — [4]Physikalisches Institut, University of Bonn, Nußallee 12, 53115 Bonn, Germany

Quantum gases of atoms and molecules in optical cavities offer a formidable laboratory for studying the out-of-equilibrium dynamics of long-range interacting systems. The interaction is mediated by multiple scattering of cavity photons and can induce emerging patterns and self-organized structures determined by the interplay of photon-mediated forces, dissipation, and quantum and thermal fluctuations. Theoretical descriptions of these phenomena often rely on mean-field or weak-coupling approximations, though their validity in this context can be limited or even questionable. In this work, we present the derivation of a Lindblad master equation for the dynamics of the sole motional variables of polarizable particles, such as atoms or molecules, that dispersively couple to cavity fields. We validate the theoretical description by showing that it captures the dynamics from weak to strong cavity-mediated interactions. Our theory provides a powerful framework for the description of out-of-equilibrium dynamics of quantum gases in cavities and their relaxation towards their steady state.

Q 71.7 Fri 12:30 P 4

Enhancing atom-photon interaction with integrated nanophotonic structures — •Xiaoyu Cheng[1], Benyamin Shnirman[1,4], Alexandra Koepf[1,4], Hadiseh Alaeian[2], Xueyi Wang[3], Sunny Yang[3], Tilman Pfau[1], and Robert Loew[1] — [1]5. Physikalisches Institut, Universitaet Stuttgart — [2]School of Electrical and Computer Engineering, Purdue University, Indiana, USA — [3]Department of Electrical Engineering, Yale University, Connecticut, USA — [4]Institut für Mikroelektronik Stuttgart (IMS-Chips), Stuttgart, Germany

Hybrid devices consisting of thermal atomic vapor and nanophotonic structures are interesting platforms for manipulating the interaction between atoms and photons. For example, we exploit cooperative effects on such hybrid platforms to study the coherent atom-photon coupling in the strong coupling regime. This requires high quality factor micro-ring cavities with small mode volume. We demonstrate that micro-rings with 700K quality factor strongly couple with multiple Rubidium atoms with collective coupling strength of several GHz, which is above the atomic decaying rate and cavity loss, results in the cooperativity C larger than 1. Moreover, we are interested in the thermal and temporal dynamics of Rb atoms experiencing strongly pulsed lasers, known as Light Induced Atomic Desorption (LIAD). With carefully designed nano-photonic structures, one can in principle probe the angular and temporal distribution of LIAD atom clouds.

Q 71.8 Fri 12:45 P 4

Design of 1D Photonic Crystal Nanobeam Cavities for Quantum Dot Integration — •Oscar Camacho Ibarra, Sandesh Kallappa Mahajan, Jan Gabriel Hartel, Atzin Ruiz Perez, Sonja Barkhofen, and Klaus Jöns — hqpd lab, PhoQS institute, CeOPP, and Department of Physics,Paderborn University, Germany

Although the design and fabrication of nanobeam cavities have been extensively explored since the early 2000s, comparatively little attention has been given to tailoring these structures for the integration of epitaxial III*V semiconductor quantum dots (QDs). This gap largely stems from the realization, around 2018, that QDs experience significant linewidth broadening when placed too close to the etched sidewalls of nanophotonic structures. Such broadening is undesirable, as it degrades photon indistinguishability, which is a key requirement for single-photon sources. In this work, we present design strategies for 1D photonic crystal nanobeam cavities with minimal impact on the optical properties of the embedded QDs.

Q 72: Quantum Technologies – Color Centers II

Time: Friday 11:00–12:45 Location: P 5

Q 72.1 Fri 11:00 P 5

Cavity-enhanced spectroscopy of the nitrogen-vacancy (NV^-) singlet transition and pump-laser-induced effects in NV-diamonds — •Tobias Probst[1], Florian Schall[1], Rüdiger Quay[1], Alexander M. Zaitsev[2], Takeshi Ohshima[3], Matthias Weidemüller[4], and Jan Jeske[1] — [1]Fraunhofer Institute for Applied Solid State Physics IAF, Freiburg, Germany — [2]College of Staten Island (CUNY), New York, USA — [3]National Institutes for Quantum Science and Technology (QST), Takasaki, Japan — [4]Universität Heidelberg, Heidelberg, Germany

Gaining a deeper understanding of the absorptive behavior of NV-diamonds in the near-infrared region is essential to optimize laser threshold magnetometry, as well as to improve enhanced sensing with long diamond light paths. With a tuneable Ti:Sa laser, the absorptive behavior of NV-diamonds was studied in a regime of 680-1060 nm, using a cavity to enhance the effects. The room temperature absorption of the microwave-sensitive NV^- singlet transition was separated from other absorbing effects. A distinctive phonon sideband was found to exist at room temperature, while the strongest change in the measurement signal occurred at the zero phonon line at 1042 nm. Several pump-laser-induced phenomena have been observed over various diamond samples and interpreted in a broad wavelength regime. They consist of an increased or decreased absorption of the Ti:Sa wavelength when pumping the NV-diamond with a green 532 nm pump laser. Possible explanations are proposed including the charge transfer between defects following ionization processes induced by the green pump laser.

Q 72.2 Fri 11:15 P 5

Electrical control for spin defects integrated in silicon carbide nanophotonic devices — •Adil Han Dogan[1], Timo Steidl[1], Pierre Kuna[1], Rainer Stöhr[1], Wolfang Knolle[2], Misagh Ghezellou[3], Jawad Ul-Hassan[3], Vadim Vorobyov[1], and Jörg Wrachtrup[1,4] — [1]3rd Institute of Physics, IQST, and Research Center SCoPE, University of Stuttgart, Stuttgart, Germany — [2]Department of Sensoric Surfaces and Functional Interfaces, Leibniz-Institute of Surface Engineering (IOM), Leipzig, Germany — [3]Department of Physics, Chemistry and Biology, Linköping University, Linköping, Sweden — [4]Max Planck Institute for Solid State Research, Stuttgart, Germany

Spin defects in silicon carbide are promising candidates for chip-scale quantum information processing. They combine atom-like optical transitions and long-lived electron and nuclear spin qubit clusters in a nanofabrication-friendly host material. Their integration in nanophotonic structures provides enhanced spin-photon interaction and increases photon collection efficiency. However, reproducible control knobs remain rare, and proximity to material interfaces in nanostructures impairs the emitter properties of the color centers. For this purpose, we develop electrical control of spin defects to mitigate near-surface spectral diffusion and offer tunability via Stark shift and Pockel's effect. Thus, we project a possible path towards on-chip quantum photonic information processing through key advances in nanofabrication and electrical control in silicon carbide.

Q 72.3 Fri 11:30 P 5

High-Q 1D photonic crystal cavities for V2 color centers in 4H-SiC — •Anantha Krishnan[1], Adil Han Dogan[1], Timo Steidl[1], Rainer Stöhr[1], Wolfgang Knolle[2], Misagh Ghezellou[2], Jawad Ul-Hassan[2], Vadim Vorobyov[1], and Jörg Wrachtrup[1,3] — [1]3rd Institute of Physics, University of Stuttgart — [2]Department of Physics, Chemistry and Biology, Linköping University — [3]Max Planck Institute for Solid State Research, Stuttgart, Germany

Scalable quantum networks rely on efficient spin photon interfaces. Existing platforms such as diamond or quantum dots offer high performance but often come with limitations in fabrication scalability or coherence properties. The V2 color center in 4H-SiC, emitting at 917 nm, combines long spin coherence with material and fabrication scalability, making it a compelling platform for integrated quantum nodes. In this work, we design high-Q 1D photonic crystal cavities to enhance the Zero-Phonon Line (ZPL) emission. Simulations of the optimized design predict a quality factor of $Q \approx 1.2 \times 10^5$ with a low mode volume, $V_{mode} \approx 1.3(\lambda/n)^3$. To realize this performance in a scalable photonic architecture, we fabricate the devices using advanced nanofabrication methods, followed by the integration of 45° undercut couplers, enabling efficient vertical excitation and collection. Transmission spectroscopy reveals narrow resonance peaks, validating the optical design. Combining high-Q engineering with efficient light coupling, this platform offers a scalable route for spin-photon interfaces in quantum networks.

Q 72.4 Fri 11:45 P 5

Electrically driven single-photon sources for scalable quantum photonics operating at the telecommunication wavelengths — •Alessandro Puddu[1,2], Junchun Yang[2], Shengqiang Zhou[1], Artur Erbe[1,2], Ahmad Echresh[1], Kambiz Jamshidi[2], and Yonder Berencén[1] — [1]Helmholtz-Zentrum Dresden-Rossendorf, Bautzner Landstrasse 400, Dresden, 01328, Germany — [2]Technische Universität Dresden, Dresden, 01069, Germany

Silicon-based quantum technologies provide a scalable platform for photonics due to their CMOS compatibility and ease of integration. Single-photon sources operating at telecom wavelengths are key components for low-loss quantum communication networks and the emerging quantum internet. Integrating these emitters with reconfigurable photonic elements such as multiplexers, modulators, filters, etc. and on-chip single-photon detectors is essential for realizing scalable quantum hardware. Optical excitation methods, however, rely on complex and alignment-sensitive laser systems, limiting their integration potential. Electrically driven color centers offer a compact and fully integrable alternative. This paper is focused on achieving electrically driven single-photon emission from individual color centers embedded in a silicon PIN diode. Emission in the telecom O- and L-bands is particularly advantageous, as it aligns with low-loss and low-dispersion regions in standard optical fibers. To improve emission efficiency and on-demand single photon generation, a single-color center will be coupled to a CMOS-compatible optical cavity, enabling Purcell-enhanced emission and efficient integration into silicon photonic circuits.

Q 72.5 Fri 12:00 P 5

Creation and theoretical modelling of highly indistinguishable single photons from tin-vacancy centers in diamond — •Robert Morsch[1], Dennis Herrmann[1], Benjamin Kambs[1], Pierre-Olivier Colard[2], Matthew Markham[2], and Christoph Becher[1] — [1]Universität des Saarlandes, FR Physik, Campus E2.6, 66123 Saarbrücken — [2]Element Six Global Innovation Centre, Fermi Avenue, Harwell Oxford, Didcot, Oxfordshire, X11 0QR, UK

In quantum information processing (QIP), various schemes require long-lived stationary qubits that allow coherent state-control, optical readout and on-demand generation of single indistinguishable photons. The tin-vacancy center (SnV^-) in diamond is a promising solid-state candidate for these applications, combining an addressable, long-lived spin and bright, longterm-stable emission of single, transform-limited photons. However, achieving near-unity photon indistinguishability remains a significant challenge. In our work we investigate the indistinguishability of resonantly excited single SnV-photons. Employing a cascade of electro-optical modulators, we carve sub-nanosecond π-pulses with record-high extinction ratios from a resonant cw-laser. We efficiently suppress the residual laser in the detection path using a home-built cross-polarization setup and measure raw HOM-visibilities of $> 95\%$, being well on par with those of single emitters in leading solid-state platforms. Detailed theoretical modelling of our experiment confirms these values and reveals an even higher intrinsic degree of the photon indistinguishabily. Considering the SnV′s long-lived spin, these findings ultimately highlight the unique potential of our platform.

Q 72.6 Fri 12:15 P 5

Strained SiV color centers coupled to a fabry perot microcavity — •Florian Feuchtmayr[1], Michael Gstaltmayr[1], Robert Berghaus[1], Selene Sachero[1], Gregor Bayer[1], Julia Heupel[2], Tobias Herzig[3], Jan Meijer[3], Cyril Popov[2], and Alexander Kubanek[1] — [1]Institut für Quantenoptik Universitat Ulm — [2]Institute of Nanostructure Technologies and Analytics, Center for Interdisciplinary Nanostructure Science and Technology, University of Kassel — [3]Division of Applied Quantum Systems, Felix Bloch Institute for Solid State Physics, University Leipzig

Group IV color centers in diamond, such as silicon vacancy (SiV), are promising for quantum optics because of their optical transitions, spin access, and good coherence properties. SiV centers typically require millikelvin temperatures, but increasing the ground state splitting improves coherence, allowing operation at higher temperatures. Here, we demonstrate the integration of a single-crystal diamond membrane into a high-finesse microcavity (F = 3000), achieving significant lifetime shortening with a Purcell factor of 2.2 in a liquid helium atmosphere. Absorption and strain spectroscopy confirm enhanced ground-state splitting, paving the way for a spin-photon interface.

Q 72.7 Fri 12:30 P 5

Raman signatures and spin relaxation mechanism of VB- in hBN quantum emitters — •Chanaprom Cholsuk[1], Viktor Ivády[2], Asli Çakan[1], Volker Deckert[3], Sujin Suwanna[4], and Tobias Vogl[1] — [1]Department of Computer Engineering, TUM School of Computation, Information and Technology, Technical University of Munich, 80333 Munich, Germany — [2]Department of Physics of Complex Systems, Eötvös Loránd University, Egyetem tér 1-3, H-1053 Budapest, Hungary — [3]Institute of Physical Chemistry, Friedrich-Schiller University, 07743 Jena, Germany — [4]Department of Physics, Mahidol University, Bangkok 10400, Thailand

Point defects in hexagonal boron nitride (hBN) are crucial for single-photon emission and can host controlled nuclear spins, making them applicable for quantum technologies. However, identifying the defects remains a challenge. Here, we propose Raman spectroscopy as a strategy for defect identification. Using density functional theory, we first benchmark the Raman signatures of the negatively-charged boron vacancy (VB-), and extend to 100 additional defects. We find that the local atomic environment is the primary determinant of the Raman lineshape, enabling discrimination among defects, as well as spin and charge states. Building on the VB- benchmark, we develop a low-temperature spin-dynamics model for T1 relaxation and demonstrate that the VB- forms a strongly coupled electron-nuclear spin core. Overall, our work establishes Raman spectroscopy as a route to defect identification, available at https://h-bn.info, and the model to capture spin interactions.

Q 73: Quantum Technologies – Solid State Systems

Time: Friday 11:00–13:00 Location: P 7

Invited Talk Q 73.1 Fri 11:00 P 7

Microwave quantum communication with rare-earth spin ensembles — •Nadezhda Kukharchyk — Walther-Meißner-Institut, Bayerische Akademie der Wissenschaften, D-85748 Garching, Germany — School of Natural Sciences, Technische Universität München, D-85748 Garching, Germany — Munich Center for Quantum Science and Technology, D-80799 Munich, Germany

Microwave quantum communication, encompassing the development of microwave quantum key distribution (QKD), quantum microwave entanglement distribution, and compatible quantum storage elements, is a highly promising area in the evolution of radio technologies toward 6G wireless networks. In our work, we focus on the development of microwave quantum memories that are compatible with microwave quantum circuits, which play a central role in quantum computing and microwave QKD protocols.

In this talk, I will present our progress in the development of broadband microwave quantum memories based on rare-earth spin ensembles, discuss their envisioned integration with microwave QKD systems, and explore potential applications in next-generation quantum communication networks.

Q 73.2 Fri 11:30 P 7

Some defects in silicon-based material – towards integrated silicon photonics — •Philipp Kellner, Bernd Hähnlein, Kevin Lauer, Christian Möller, Kai Kühnlenz, Mario Bähr, and Thomas Ortlepp — CIS Inst. für Mikrosensorik, Konrad-Zuse-Straße 14, 99099 Erfurt

For years Silicon is known as the standard VIS and NIR sensor material, although an indirect semiconductor. It is still a material of choice for optoelectronics, due to known handling and structuring procedures as well as CMOS-compatibility allowing for highly integrated devices. The given presentation will shed light on defect-based light emitter in indium-doped silicon and gallium implanted silicon-nitride, showing generation methods and photoluminescence spectra. Abbe-limited optical microscopy is going to be used for imaging and photostability will be estimated. These experiments will undertake very first steps towards small light sources on silicon chips and in turn integrated silicon photonics.

Q 73.3 Fri 11:45 P 7

Toward an Efficient Quantum-Photonic Interface for Rare-Earth Ions on a Hybrid LNOI-TiO_2 Platform — •Tobias Feuerbach[1], Georgii Grechko[1], Christopher Ng[1], Roman Kolesov[1], and Jörg Wrachtrup[1,2] — [1]3rd Institute of Physics, University of Stuttgart, Germany — [2]Max Planck Institute of Solid State Research, Stuttgart, Germany

Over the years rare-earth ions (REIs) have gained attention for quantum memory applications due to their telecom wavelength compatibility and exceptional coherence times. Their low photon rates, however, make cavity-enabled Purcell enhancement necessary.

Hybrid-material photonic crystal cavities (PCCs) are a promising approach for photonic integration of REIs, combining the strengths of different materials. We employ a hybrid photonic system that merges lithium niobate on insulator (LNOI), offering electro-optical tunability and scalable fabrication, with TiO_2, a high-index and spin-free host for REIs, enabling scalable, tunable and efficient quantum photonic interfaces at telecom wavelength.

We compare techniques for Er^{3+} integration into rutile TiO_2 waveguides and discuss our hybrid TiO_2/LNOI process, that is based on the fabrication of freestanding TiO_2 structures, Van-der-Waals bonding to x-cut LNOI and subsequent nanofabrication of the combined stack. Specifically, tunable hybrid PCCs made from TiO_2/LNOI are presented. A loaded Q-factor of 42k and a tunability of 0.8 GHz/V is achieved. We use a bifocal microscope for spectral characterization, enabled by a custom freespace-to-chip coupling technique.

Q 73.4 Fri 12:00 P 7

Detecting Bell-Operator Correlations in Superconducting Devices — Ke Wang[1], Weikang Li[2], Shibo Xu[1], Mengyao Hu[3], Jiachen Chen[1], Yaozu Wu[1], Chuanyu Zhang[1], Feitong Jin[1], Xuhao Zhu[1], Yu Gao[1], Ziqi Tan[1], Zhengyi Cui[1], Aosai Zhang[1], Ning Wang[1], Yiren Zou[1], Tingting Li[1], Fanhao Shen[1], Jiarun Zhong[1], Zehang Bao[1], Zitian Zhu[1], Zixuan Song[1], Jinfeng Deng[1], Hang Dong[1], Xu Zhang[1], Pengfei Zhang[1], Wenjie Jiang[1], Zhide Lu[1], Zheng-Zhi Sun[1], Hekang Li[1], Qiujiang Guo[1], Zhen Wang[1], •Patrick Emonts[3,4], Jordi Tura[3], Chao Song[1], Hao Wang[1], and Dong-Ling Deng[2] — [1]Zhejiang University, China — [2]Tsinghua University, China — [3]Leiden Univsersity, The Netherlands — [4]Ulm University, Germany

Quantum nonlocality represents a stronger form of quantum correlation than entanglement and defies Einstein's notion of local realism. It serves as a key resource for applications such as cryptography or certified randomness. Yet, detecting nonlocality in many-body systems remains highly challenging. In this talk, I present the experimental viability of Hamiltonians to certify genuine multipartite Bell-Operator correlations in systems up to 24 qubits on a programmable superconducting processor. As an example, we variationally prepare a low-energy state of a 73-qubit honeycomb model and certify its Bell-Operator correlations by measuring an energy exceeding the classical bound by 48 standard deviations. This establishes a practical route for preparing and certifying multipartite Bell correlations as a stronger benchmark beyond entanglement (Phys. Rev. X 15, 021024, 2025).

Q 73.5 Fri 12:15 P 7

Effect of Heterostrain on the Photophysical Properties of WSe2/MoSe2 Heterobilayers — •Hilal Korkut and Ibrahim Sarpkaya — Bilkent University, UNAM (National Nanotechnology Research Center), Ankara, Turkey

Transition metal dichalcogenides have attracted broad interest due to their exceptional mechanical, electronic, and optical properties1. Owing to their long lifetime, permanent out-of-electric dipole, and high tunability provide an excellent platform for exploring correlated interactions and valley-dependent physics2. In this talk, I will present how heterostrain modifies the low-temperature optical responses of interlayer excitons in WSe2/MoSe2 heterobilayers and demonstrate how strain can be utilized as a means of controlling these properties. References 1.*Wang, G. et al. Colloquium: Excitons in atomically thin transition metal dichalcogenides. Rev. Mod. Phys. 90, 21001 (2018). 2.*Durmuş, M. A., Demiralay, K., Khan, M. M., Atalay, Ş. E. & Sarpkaya, I. Prolonged dephasing time of ensemble of moiré-trapped interlayer excitons in WSe2-MoSe2 heterobilayers. npj 2D Mater. Appl. 2023 71 7, 1*8 (2023).

Q 73.6 Fri 12:30 P 7

Nanophotonic engineering to enhance laser cooling via Erbium ions — •Nilesh Goel, Florian Burger, Andrew Propper, Stephan Rinner, Andreas Gritsch, Kilian Sandholzer, and Andreas Reiserer — Technical University of Munich, TUM School of Natural Sciences, Physics Department and Munich Center for Quantum Science and Technology (MCQST), James-Franck-Str. 1, 85748 Garching, Germany

The cooling of solid-state quantum systems is a key requirement for their coherent operation. Conventional cryocoolers are limited by their large size, power consumption, and added vibrations. Therefore we explore an alternative route: on-chip laser cooling of silicon nanostructures using erbium dopants as local refrigerants. While direct optical refrigeration of semiconductors is challenging, erbium ions embedded in a nanophotonic slow-light waveguide can efficiently pump entropy from the phonon bath into a guided light mode. In a first experiment, we show how this allows for accurate temperature measurement [1]. To enhance the cooling process, we then use slow-light engineering to tailor the local density of states over a broad spectral range. This way we can suppress the unwanted radiative channels [2] to suppress competing decay pathways, thereby improving the cooling efficiencies of the system. We show the current progress towards this goal and outline the next steps toward enhanced laser cooling in solid state systems.

[1] K. Sandholzer et al., Nanophotonics 14, 2005 (2025).
[2] F. Burger et al., arXiv:2511.23301 (2025).

Q 73.7 Fri 12:45 P 7

Optically detected nuclear magnetic resonance of coherent spins in a molecular complex — •Vishnu Unni Chorakkunnath, Evgenij Vasilenko, Preethika Thiraviam, Nicholas Jobbitt, Barbora Brachnakova, Senthil Kuppusamy, Mario Ruben, and David Hunger — Karlsruher Institut für Technologie, Karlsruhe, Germany

A europium-based molecular complex has recently shown [1] competitive optical coherence time, surpassing those of europium-doped solid-state nanocrystals. Molecular complexes offer the possibility of tailoring ligand fields to improve and control optical and spin properties to realize optically addressable spin qubits. We report the first optically detected nuclear magnetic resonance (ODNMR) in a molecular complex. We observe nuclear Rabi-oscillations and spin coherence times (T2) of ~600*s in a single-crystal sample of the molecular complex at 4.2K. The spin coherence is extended up to 2ms with dynamical decoupling. Furthermore, we report strong nuclear and optical transition frequency correlation [2]. The self-assembly of molecular complexes into high-quality crystals improves optical and spin properties. Such crystals can be integrated into fibre-based microcavities [3] to enhance emission rates by the Purcell effect. These results are important steps towards single Eu3+ ion experiments to realize optically addressable spin qubits.

[1] Serrano et al., Nature, 603, 241-246 (2022)
[2] Vasilenko et al., arXiv:2509.01467 (2025)
[3] Eichhorn et al., Nanophotonics 14, 1817 (2025)

Q 74: Quantum Information – Concepts and Methods

Time: Friday 11:00–13:00 Location: P 10

Q 74.1 Fri 11:00 P 10

Computational Capabilities and Compilation Strategies for Trapped-Ion Quantum Computers — •Jurek Eisinger[1], Ludwig Schmid[2], Daniel Schönberger[2], Janine Hilder[1,3], Christian Marciniak[3], Ulrich Poschinger[1], Ferdinand Schmidt-Kaler[1], and Robert Wille[2] — [1]QUANTUM, University of Mainz, Department of Physics, Staudingerweg 7, Germany — [2]Chair for Design Automation, Technical University of Munich, Germany — [3]neQxt, 63906 Erlenbach am Main, Germany

Trapped-ion quantum computers mature to larger qubit numbers, but their computational capability is limited by architectural and control constraints. We present a framework for quantifying and optimizing the computational capabilities of trapped-ion processors. Using compiler techniques from classical computer science, we show how arbitrary quantum circuits can be mapped to hardware-efficient sequences of operations, optimized for metrics such as shuttling distance and gate overhead. The approach is demonstrated for both 1D and 2D [Schoenberger et al., Proc. IEEE QSW (2025), DOI: 10.1109/QSW67625.2025.00023] shuttling architectures, and extended toward logical qubit encodings to support fault-tolerant operations in future large-scale systems. In this context, we introduce a universal routing and scheduling algorithm for a shuttling-based trapped-ion quantum computer that efficiently orchestrates qubit register reconfiguration, and gate execution, tailored to varying levels of ion-qubit connectivity.

Q 74.2 Fri 11:15 P 10

Studying the feasibility of distributed quantum computing enabled via satellite communication — •Lukas Pausch[1], Davide Orsucci[2], Philipp Kleinpass[2], Alexander Sauer[1], Florian Moll[2], and Matthias Zimmermann[1] — [1]Deutsches Zentrum für Luft- und Raumfahrt e.V. (DLR), Institute of Quantum Technologies, Ulm, Germany — [2]Deutsches Zentrum für Luft- und Raumfahrt e.V. (DLR), Institute of Communications and Navigation, Oberpfaffenhofen, Germany

In future quantum networks, satellite-mediated quantum communication could be used to enable distributed quantum computing (DQC). In this talk, we present the current state of our ongoing analysis on potential use cases for satellite-enabled distributed quantum computing and on their feasibility based on hardware restrictions and algorithm requirements: On the one hand, we investigate entanglement distribution via satellites, considering different orbits and entanglement distribution schemes, and we evaluate restrictions regarding, e.g., entanglement distribution rates or connection times. On the other hand, we analyse and assess possible DQC applications that might require long-range communication. Furthermore, we investigate the current state of the art of quantum-computing hardware and interconnects between matter qubits and flying qubits (photons), with a particular focus on DQC. These considerations will enable us to evaluate the gap to be bridged by future developments and to identify the necessary steps to be taken for a future implementation of satellite-enabled DQC.

Q 74.3 Fri 11:30 P 10

QuKAN: A Quantum Circuit Born Machine Approach

to Quantum Kolmogorov Arnold Networks — •Yannick Werner[1,2], Akash Malemath[2], Mengxi Liu[1], Vitor Fortes Rey[1,2], Nikolaos Palaiodimopoulos[1,2], Paul Lukowicz[1,2], and Maximilian Kiefer-Emmanouilidis[1,2] — [1]DFKI Kaiserslautern — [2]RPTU Kaiserslautern-Landau

Kolmogorov Arnold networks, based on the Kolmogorov Arnold representation theorem, provide a compact alternative to conventional neural networks by placing learnable functions on edges rather than nodes. While highly expressive in classical settings, their potential in quantum machine learning remains largely unexplored. In this work, we present an implementation of these KAN architectures in both hybrid and fully quantum forms using a Quantum Circuit Born Machine. We adapt the KAN transfer using pre-trained residual functions, thereby exploiting the representational power of parametrized quantum circuits. In the hybrid model we combine classical KAN components with quantum subroutines, while the fully quantum version the entire architecture of the residual function is translated to a quantum model. We demonstrate the feasibility, interpretability and performance of the proposed Quantum KAN (QuKAN) architecture.

Q 74.4 Fri 11:45 P 10

Exploring Disorder Effects in Quantum Generative Models — •Nikolaos Palaiodimopoulos[1,2], Yannick Werner[1,2], Jasmin Frkatovic[1], Vitor Fortes Rey[1], Matthias Tchöpe[2], Sungho Suh[2], Paul Lukowicz[1,2], and Maximilian Kiefer-Emmanouilidis[1,2] — [1]RPTU Kaiserslautern-Landau — [2]DFKI Kaiserslautern

Disordered quantum many-body systems (DQS) and quantum neural networks (QNNs) exhibit strong structural parallels, with a DQS effectively functioning as a QNN with randomly initialized parameters. We show that random processes can act as a deceptive quantum generative mechanism in QNNs, where unitarity preserves memory effects absent in classical networks. These effects impact both the learnability and trainability of QNNs and can lead to an overestimation of their generative capabilities. While DQS can be useful for tasks such as image augmentation, we caution that evaluations on overly simple datasets may misrepresent the true power of current quantum generative models.

Q 74.5 Fri 12:00 P 10

On the Generalization Limits of Quantum Generative Adversarial Networks with Pure State Generators — Jasmin Frkatovic[1], •Akash Malemath[1], Ivan Kankeu[1], Yannick Werner[1,2], Matthias Tschöpe[1], Vitor Fortes Rey[1,2], Sungho Suh[3], Paul Lukowicz[1,2], Nikolaos Palaiodimopoulos[1,2], and Maximilian Kiefer Emmanouilidis[1,2] — [1]RPTU Kaiserslautern-Landau — [2]DFKI, Kaiserslautern — [3]Korea University, Seoul

Quantum Generative Adversarial Networks (QGANs) have emerged as promising candidates for quantum-enhanced generative modelling, yet their practical capabilities remain insufficiently understood. In this work, we investigate the generalization performance of two state-of-the-art fully quantum GAN architectures, QuGAN and IQGAN, in image generation tasks. Using extensive numerical experiments on MNIST and CIFAR-10, we systematically show that both models fail to learn the underlying data distribution and instead converge to reproducing only the dominant average features of each class, even under multi-class training and increased circuit expressivity. To explain these empirical failures, we derive an analytic lower bound on the achievable fidelity of pure-state quantum generators. Using the Helstrom bound, we prove that any QGAN whose generator outputs a single pure quantum state cannot approximate high-rank data distributions beyond the fidelity associated with the dataset's leading eigenvector. Our results highlight intrinsic expressivity bottlenecks in current QGAN designs and motivate the development of quantum generators capable of producing mixed-state outputs or incorporating non-linear mechanisms.

Q 74.6 Fri 12:15 P 10

Applications of blind quantum computation - hiding a Grover search algorithm — •Alexander Sauer, Alexander von Consbruch, and Matthias Zimmermann — German Aerospace Center (DLR), Institute of Quantum Techologies, Wilhelm-Runge-Straße 10, Ulm, 89081, Germany

With quantum-capable devices becoming readily available and the ongoing development of quantum computers, quantum networks are within grasp. Apart from the enhanced computational power of quantum computers, these networks also provide new opportunities in security and secrecy. One new method that becomes available is blind quantum computing, in which a powerful quantum computer acts as a server and performs computations for a distant client without getting knowledge about details of the computation [1]. We investigate applications of blind quantum computing and the introduced overhead on communication between the involved parties and complexity on the quantum server. In particular, we present a protocol for a hidden Grover search algorithm utilizing additional qubits on a quantum server which are securely initialized by the client.

[1] Fitzsimons, J.F. (2017), npj Quantum Information 3(1), 23.

Q 74.7 Fri 12:30 P 10

Two-qubit encoding strategy for a continuous quantum system — •Sebastian Luhn and Matthias Zimmermann — DLR e.V., Institut für Quantentechnologien, Ulm

Bosonic codes employ particular states of an infinite-dimensional Hilbert space to encode a qubit within a continuous quantum system. Despite the enormous resources available in a continuous quantum system [1], typical encodings only exist for single qubits [2]. Here we go one step further and present an encoding scheme for two qubits (four states), which protects against errors in small shifts of the canonical variables position q and momentum p. Furthermore, we present a universal set of single and two-qubit operations, based on particular symmetry operations for continuous quantum states represented by a square lattice in phase space.

[1] Lloyd, S. and Braunstein, S., Quantum Computation over Continuous Variables, Phys. Rev. Lett. **82**, 1784-1787 (1999).

[2] Gottesman, D., Kitaev, A., and Preskill, J., Encoding a qubit in an oscillator, Phys. Rev. A **64**:012310 (2001).

Q 74.8 Fri 12:45 P 10

Exploring Multi-class Image Segmentation Through Localization Phenomena — •Akshaya Srinivasan[1,2], Yannick Werner[2,3], Alexander Geng[1], Berta Garcia Heras[3], Ali Moghiseh[1], Alexey Bochkarev[2], and Maximilian Kiefer-Emmanouilidis[2,3] — [1]Fraunhofer ITWM, Kaiserslautern — [2]RPTU Kaiserslautern-Landau, Kaisersluatern — [3]DFKI, Kaiserslautern

We propose an unsupervised, quantum-inspired method for multi-class segmentation of abdominal CT scans based on Anderson localization in image-derived 2D lattice Hamiltonians. Each CT slice is mapped onto a lattice in which pixel intensities define a disordered on-site potential, while nearest-neighbor hopping terms are set by a Gaussian similarity kernel that encodes local image structure. This formulation induces Anderson-like localization of eigenstates driven by contrast variations across the image. Diagonalization of the resulting single-particle Hamiltonian enables segmentation by binning eigenmodes according to their localization lengths, which naturally correspond to anatomical scales. Distinct clusters of localized states align with major anatomical regions, including liver, pancreas, kidneys, and background, producing coherent multi-label segmentation masks without annotated data, pre-processing, or model training. Validation on clinical abdominal CT datasets demonstrates robust performance under varying contrast and noise conditions. The framework is purely linear-algebraic and highlights the potential of Hamiltonian-based models and localization physics for interpretable, physics-driven medical image analysis and quantum-inspired computer vision algorithms.

Q 75: Quantum Systems between Bose and Fermi Statistics

Time: Friday 11:00–12:30 Location: P 11

Q 75.1 Fri 11:00 P 11

Encoding gauge theories in quantum systems — •Alessio Celi — Departament de Física, Universitat Autònoma de Barcelona, 08193 Bellaterra, Spain

In this talk, I will describe a quantum computation/simulation approach to gauge theories based on the encoding, the resolution of the local conservation law of the theory to reformulate it in terms of the physical states, the gauge invariant degrees of freedom. I will present successful applications of the encoding that ranges from the realization of topological gauge theories with ultracold atoms to the ab-initio continuum limit of 2D lattice gauge theories with tensor networks.

Q 75.2 Fri 11:15 P 11

Finite-Size Effect in Anyonic Schulz-Shastry Models — Borna Perkovic[1], •Martin Bonkhoff[2], and Thore Posske[2] — [1]Physics Department, Massachusetts Institute of Technology, 182 Memorial Dr, Cambridge, MA 02139, USA — [2]I. Institut für Theoretische Physik, Universität Hamburg, 22607 Hamburg, Germany

Luttinger liquid theory for canonical particles or spins is typically spatio-temporally symmetric, as dictated by the symmetries of the underlying lattice models. In contrast, for one-dimensional anyons, additional fixed points arise that feature spatio-temporally asymmetric marginal couplings, belonging to the Schulz-Shastry class [1]. We investigate the finite-size effects of a two-leg model that captures anyonic low-energy excitations in a saturated spin-1/2 chain with next-nearest-neighbour interactions [2]. We compute boundary characteristics such as Friedel oscillations and persistent currents, and determine both the bulk and boundary limits of correlation functions [1] K. V. Pham, M. Gabay and P. Lederer, EPL 51 161 (2000). [2] Rahmani, Armin and Feiguin, Adrian E. and Batista, Cristian D. Phys. Rev. Lett. 113, 267201 (2014).

Q 75.3 Fri 11:30 P 11

Anyonic phase transitions in the 1D extended Hubbard model with fractional statistics — •Imke Schneider[1], Martin Bonkhoff[2], Kevin Jägering[1], Axel Pelster[1], Shijie Hu[3], and Sebastian Eggert[1] — [1]University of Kaiserslautern-Landau (RPTU) — [2]University of Hamburg — [3]Beijing Computational Science Research Center

Recent advances in quantum technology allow the realization of "lattice anyons", which have enjoyed large interest as particles which interpolate between bosonic and fermionic behavior. We now study the interplay of such fractional statistics with strong correlations in the one-dimensional extended Anyon Hubbard model at unit filling by developing a tailored bosonization theory and employing large-scale state-of-the-art numerical simulations. The resulting phase diagram shows several distinct gapped and superfluid phases, which display an interesting transition through a multicritical point as the anyonic exchange phase is tuned from bosons to fermions. The universality of the phase transitions is discussed.

Q 75.4 Fri 11:45 P 11

Three-body bound states in the anyon-Hubbard model — •Isaac Tesfaye[1], Joyce Kwan[2], Markus Greiner[2], Luis Santos[3], André Eckardt[1], and Brice Bakkali-Hassani[2] — [1]Institut für Physik und Astronomie, Technische Universität Berlin, Hardenbergstraße 36, 10623 Berlin, Germany — [2]Department of Physics, Harvard University, Cambridge, Massachusetts 02138, USA — [3]Institut für Theoretische Physik, Leibniz Universität Hannover, Appelstr. 2, 30167 Hannover, Germany

Quantum statistics in low-dimensional systems predicts anyonic particles with fractional exchange statistics, which are neither bosons nor fermions. While anyons are typically found in 2D, as excitations of topologically ordered states of matter, recently anyon-like exchange has also been observed in two different experimental realizations of the anyon-Hubbard model (AHM). The AHM can be formulated in terms of bosons featuring density-dependent Peierls phases, described by a statistical phase angle θ. This angle has been shown to control asymmetric transport and the formation of dynamically bound pairs at finite momentum. Here, we show theoretically that the AHM also hosts three-body bound states in and outside the continuum. We provide a simple approximation to these three-body bound states using a variational ansatz and explain their binding mechanism. Moreover, we reveal that the signatures of three-body bound states in the AHM can be directly probed experimentally from the expansion dynamics starting from three localized particles.

Q 75.5 Fri 12:00 P 11

Quantum many-body scars in the tilted anyon-Hubbard model — •Ana Hudomal[1], Ivana Vasić[1], and Axel Pelster[2] — [1]Institute of Physics Belgrade, University of Belgrade, Serbia — [2]Physics Department and Research Center OPTIMAS, RPTU Kaiserslautern-Landau, Germany

Quantum many-body scarring is a form of weak ergodicity breaking in which a small set of nonthermal eigenstates are embedded in an otherwise ergodic spectrum [1]. Scarring has been observed in both the tilted Bose-Hubbard model [2] and the tilted Fermi-Hubbard model [3], even though the underlying mechanisms appear to differ. Interestingly, in both models scarring appears in the same parameter regime and at unit filling, suggesting a deeper connection between them. Here we interpolate between bosonic and fermionic statistics by tuning the statistical angle θ in the anyon-Hubbard model [4] with open boundary conditions and a linear tilt potential. We identify characteristic signatures of scarring, including periodic revivals and atypical eigenstates, and investigate how their properties evolve as a function of θ.

[1] M. Serbyn *et al.*, Nat. Phys. **17**, 675 (2021).
[2] G.-X. Su *et al.*, Phys. Rev. Research **5**, 023010 (2023).
[3] J.-Y. Desaules *et al.*, Phys. Rev. Lett. **126**, 210601 (2021).
[4] T. Keilmann *et al.*, Nat. Commun. **2**, 361 (2011).

Q 75.6 Fri 12:15 P 11

Estimating universal parameters of 1D anyons via Bogoliubov theory — •Bin-Han Tang[1], Axel Pelster[2], and Martin Bonkhoff[3] — [1]University of Trento, Italy — [2]RPTU Kaiserslautern-Landau, Germany — [3]University of Hamburg, Germany

Recently, the one-dimensional anyon-Hubbard model was realized in a seminal experiment with Cs-atoms [1]. This allowed to confirm previous theoretical predictions that the quasi-momentum distribution is asymmetric for intermediate statistical angles, reflecting inherent spatio-temporal asymmetry. In one-dimensional systems of infinite extent, Bose-Einstein condensation is precluded by strong quantum fluctuations, and the Luttinger paradigm is the governing principle instead. However, for non-integrable models the coupling constants of the theory are only known analytically in weak-coupling limit, and have to be deduced numerically or with approximate methods in general. To this end, we use a thermodynamic description via a Landau potential, which has to be extremal with respect to both the density and the wave vector characterizing the effective condensate in [1]. The latter induces a current-density coupling as an additional response coefficient, apart from the ordinary density stiffness and phase stiffness. Imposing thermodynamic stability then implies different sound velocities for the propagation to the left or the right. And we compare the stiffnesses with the predictions of Luttinger liquid theory for the anyon-Hubbard model in the dilute limit, where we can slightly extend to higher filling fractions [2]. [1] S. Dhar et al., Nature 642, 53 (2025). [2] M. Bonkhoff et al. Phys. Rev. Lett. 126, 163201 (2021).

Q 76: Ultra-cold Atoms, Ions and BEC V (joint session A/Q)

Time: Friday 11:00–13:00 Location: N 1

Invited Talk Q 76.1 Fri 11:00 N 1

Toolbox for of Rydberg state engineering in trapped ions — •Robin Thomm, Vinay Shankar, Natalia Kuk, and Markus Hennrich — Department of Physics, Stockholm University

Trapped Rydberg ions offer a novel approach that combines the advantages of deep, state independent confinement and excellent external and internal control found in trapped ions with the scaling of key atomic properties, such as polarizability and interaction strengths, of Rydberg states. By coherently moving between different Rydberg states in a controlled manner, one could tune these parameters to maximize effects like inter-ion coupling and minimize adverse effects. We demonstrate such control of Rydberg S and P states coupled by microwave radiation. We show Rabi oscillations on the nanosecond timescale with 96% fidelity and demonstrate adiabatic transfer between different dressed states on the sub-microsecond timescale, fast enough for multiple transfer operations within the lifetime of the short-lived Rydberg states. The techniques developed pave the way for more sophisticated quantum simulation and sensing applications, especially for Rydberg experiments with longer ion strings where ground state cooling is difficult to achieve, or where different Rydberg states are desired.

Q 76.2 Fri 11:30 N 1

Hybrid van Hove approach to mixed quantum-classical gases — •Maja Maschke[1,2] and Sebastian Ulbricht[1,2] — [1]Institut für Mathematische Physik, Technische Universität Braunschweig, Braunschweig, Germany — [2]Fundamental Physics for Metrology, Physikalisch-Technische Bundesanstalt PTB, Braunschweig, Germany

In cold matter physics, the search for effective approximation schemes is a constant one due to the difficulty of many-particle calculations at the fully quantum level. One set of such schemes are semi-classical approaches in which one sector of a quantum system is treated classically. Historically, such hybrid theories have often been proposed ad-hoc, rather than being derived from a set of first principles. Recently, an axiomatic approach to mixed quantum-classical systems based on a Hilbert space formulation of classical mechanics due to van Hove has been proposed [1]. To date, the consistency of this novel approach was demonstrated at the few-particle level only. In this talk, we extend this work to many-particle systems and discuss its applicability to cold bosonic gases. We will demonstrate how to derive a mean field theory of an interacting hybrid gas at finite temperature featuring a quantum ground state (BEC) and a classical thermal cloud. We present a quantitative analysis of the critical temperature and the condensate fraction and compare our self-consistent numerical approach to the well-established ZNG theory. Our results mark a successful consistency check for the hybrid van Hove-formalism and illustrate to which extent a purely classical description of the thermal cloud is sufficient.

[1] M. Reginatto et al 2025 J. Phys.: Conf. Ser. 3017 012037

Q 76.3 Fri 11:45 N 1

Observation of a structural transition in dipolar (super)solids — •Karthik Chandrashekara, Jianshun Gao, Christian Gölzhäuser, Lily Platt, Wyatt Kirkby, Manon Ballu, and Lauriane Chomaz — Physikalisches Institut der Universität Heidelberg, Heidelberg, Germany

Spontaneous formation of spatially nonuniform, periodic structures from homogeneous backgrounds is well known in classical systems and has analogues in quantum matter, where interactions can generate such patterns even at equilibrium. Dipolar Bose gases provide a striking example: long-range, anisotropic dipole-dipole interactions stabilized by quantum fluctuations yield ordered crystalline phases that may remain superfluid, first observed in one-dimensional geometries and later in planar systems. For a planar dipolar Bose gas with transverse dipole orientation, extended mean-field theory predicts triangular droplet, stripe, and honeycomb-like structures. Transitions from unmodulated to these modulated states are generally first order except at a critical point allowing a continuous transition. Tilting the dipoles from the plane normal alters these boundaries, broadening the stripe region and introducing new critical points. Varying the scattering length can thus drive transitions to triangular droplet or stripe phases depending on the density and angle. Here, we experimentally explore the phase diagram of a dipolar gas in a surfboard-shaped trap using interaction ramps and control of dipole tilts. We observe the formation of crystalline phases, including a tilt-induced stripe-like (super)solid, and investigate the structural transitions between the morphologies.

Q 76.4 Fri 12:00 N 1

Localized to Delocalized: Radial Eigenmodes in a Tapered Ion Trap — •Moritz Göb[1], Manika Bhardwaj[1], Bogomila Nikolova[2], Bernd Bauerhenne[1], Peter Ivanov[2], and Kilian Singer[1] — [1]Experimentalphysik 1, Universität Kasssel — [2]Center for Quantum Technologies, Department of Physics, St. Kliment Ohridski University of Sofia

The tapered ion trap, originally proposed for the single ion heat engine [1], exhibits position-dependent radial confinement [2]. Investigating the motional resonances of two- or three-ion crystals in this trap reveals distinct eigenmode characteristics differing from those in linear ion traps.

At weak axial confinement, the inter-ion coupling is minimal, resulting in localized modes where each ion oscillates at a distinct frequency. In contrast, stronger axial confinement leads to the emergence of delocalized eigenmodes, akin to those observed in linear ion traps.

This presentation will explore the implications of these findings for quantum optics and quantum information applications, highlighting the potential benefits of tapered ion traps in these fields.

[1] J. Roßnagel, S.T. Dawkins, K. N. Tolazzi, O. Abah, E. Lutz, F. Schmidt-Kaler, K. Singer, Science 352, 325 (2016).

[2] B. Deng, M. Göb, M. Masuhr, J. Roßnagel, G. Jacob, D. Wang, K. Singer, Quantum Sci. Technol. 10, 015017 (2025).

Q 76.5 Fri 12:15 N 1

Dark Energy search using atom interferometry in microgravity — •Sukhjovan Singh Gill[1], Magdalena Misslisch[1], Charles Garcion[1], Alexander Heidt[2], Ioannis Papadakis[3], Christoff Lotz[2], Sheng-Wey Chiow[4], Nan Yu[4], and Ernst Rasel[1] — [1]Institut für Quantenoptik, Leibniz Universität Hannover, Germany — [2]Institut für Transport- und Automatisierungstechnik, Leibniz Universität Hannover, Germany — [3]Institut für Physik, Humboldt Universität zu Berlin, Germany — [4]Jet Propulsion Laboratory, California Institute of Technology, Pasadena, USA

The nature of dark energy is one of the biggest quests of modern physics and is required to explain the accelerated expansion of the universe. In the chameleon theory, a scalar field is proposed that is hidden by a screening effect in the vicinity of bulk masses, thereby making the model consistent with observations. The DESIRE project studies the chameleon field model using BEC of ^{87}Rb atoms as a source in a microgravity environment. The Einstein-Elevator at Leibniz University Hannover provides 4 seconds of microgravity time for multi-loop atom interferometry to search for phase contributions induced by chameleon fields shaped by a changing mass density. This work will further constrain thin-shell models for dark energy by several orders of magnitude. The BEC is transported via Bloch oscillations from the atom chip to the test-mass to perform atom interferometry.

Q 76.6 Fri 12:30 N 1

Quantum Simulation of Excitons in Ultracold Dipolar Fermi Gases in Optical Lattices — •Florian Hirsch[1], Oriana Diessel[2], Rafal Oldziejewski[3], and Richard Schmidt[1] — [1]Institute for Theoretical Physics, Heidelberg University, Heidelberg, Germany — [2]ITAMP, Harvard-Smithsonian Center for Astrophysics, Cambridge, Massachusetts 02138, US — [3]Max-Planck- Institute of Quantum Optics, Hans-Kopfermann-Strasse 1, 85748 Garching, Germany

Ultracold atoms have emerged as a powerful platform for simulating condensed matter phenomena, offering insights into effects difficult to analyze in detail in solid-state systems. Inspired by the progress on the study of exciton physics in atomically thin semiconductors, we investigate the formation of analogs of excitons in cold atomic systems. Using dipolar Fermions in a hexagonal optical lattice with an energy offset between trigonal sublattices, we predict the existence of cold atomic excitons and show that cold atoms allow to study excitons across the whole interaction range, from weak interactions when electron mass models can be applied to flat band models at strong interactions. We demonstrate how these excitons can be observed using lattice modulation spectroscopy, and we show that both time-of-flight spectroscopy and high-resolution quantum gas microscopy can be used to map out the exciton wavefunction. Establishing the core idea of quantum simulation of semiconductor physics, this work lays the foundation for simulating complex electronic states found in semiconductors, including trions, polarons, exciton insulators and condensates.

Q 76.7 Fri 12:45 N 1

Spin-resolved microscopy of an SU(N) Fermi-Hubbard system — •Leonardo Bezzo[1], Carlos Gas-Ferrer[1], Sandra Buob[1], Antonio Rubio-Abadal[1], and Leticia Tarruell[1,2] — [1]ICFO, Castelldefels (Barcelona), Spain — [2]ICREA, Barcelona, Spain

Quantum-gas microscopes have provided direct access to the phases of the Fermi-Hubbard model. For SU(2) systems, they have brought microscopic insight into the complex competition between interactions, quantum magnetism, and doping. Alkaline-earth(-like) fermions extend this spin-1/2 paradigm by giving access to SU(N) Fermi-Hubbard models, with rich phase diagrams to be unveiled. Despite its fundamental interest, a microscopic exploration of SU(N) quantum systems has remained elusive. We report the realization of a quantum-gas microscope for fermionic ^{87}Sr. Our fluorescence imaging scheme, based on cooling and detection on the narrow intercombination line at 689 nm, enables spin-resolved single-atom detection. By combining it with an optical pumping protocol, we are able to detect the 10 spin states occupation in a single experimental run, a crucial capability for probing site-resolved magnetic correlations. Moreover, we characterize the fundamental inelastic photon scattering processes that limit the site-resolved fidelity of our imaging protocol, and demonstrate an extension of our method that allows us to reach fidelities > 96% for systems up to SU(8). These results establish ^{87}Sr quantum-gas microscopy as a powerful approach to study exotic magnetism in the SU(N) Fermi-Hubbard model, and provide a new detection tool with potential applications to quantum simulation, computation, and metrology.

Q 77: Photonics – 3D Printing

Time: Friday 14:30–16:15 Location: P 2

Q 77.1 Fri 14:30 P 2

High-Fidelity Transfer of 3D-Printed Freeform Micro-Optics into Scalable Polymer Replication — •Leander Siegle[1], Stefan Wagner[2,3], Stephan Haeusler[3], Philipp Flad[1], Mario Hentschel[1], Thomas Günther[2], André Zimmermann[2,3], and Harald Giessen[1] — [1]4th Physics Institute, University of Stuttgart, Pfaffenwaldring 57, 70569 Stuttgart, Germany — [2]Institute for Micro Integration (IFM), Allmandring 9B, 70569 Stuttgart, Germany — [3]Hahn-Schickard, Allmandring 9B, 70569 Stuttgart, Germany

We present a scalable process for fabricating aspherical and hybrid achromatic micro-lens arrays by combining two-photon polymerization grayscale lithography with electroplating and injection molding. Master structures containing 1632 lenses with 100-300 μm diameter and 100-1000 μm focal length were 3D-printed using a Nanoscribe Quantum X and replicated in cyclic olefin copolymer (TOPAS 5013L-10) using nickel molds. The replicas showed sub-micron deviations and a surface roughness of 6-20 nm, comparable to the 3D-printed masters (4-17 nm). Optical tests confirmed close to diffraction-limited focusing, and high-contrast and distortion-free imaging up to 161 lp/mm. Hybrid lenses maintained achromatic performance across 500-700 nm. Our method enables high-fidelity, cost-efficient mass production of freeform and hybrid micro-optics for imaging, sensing, and photonic integration.

Q 77.2 Fri 14:45 P 2

Compact 3D-printed dark-field condenser for high-resolution optical microscopy — •Robert Horvat[1], Leander Siegle[1], Luca Schmid[1], Pavel Ruchka[2], Philipp Flad[1], Monika Ubl[1], Michael Schmid[2], Lukas Wesemann[3,4], and Harald Giessen[1] — [1]4th Physics Institute and Research Center SCoPE, University of Stuttgart, Pfaffenwaldring 57, 70569 Stuttgart, Germany — [2]Printoptix GmbH, Nobelstraße 15, 70569 Stuttgart, Germany — [3]School of Physics, The University of Melbourne, Victoria 3010, Australia — [4]ARC Centre of Excellence for Transformative Meta-Optical Systems, School of Physics, The University of Melbourne, Victoria 3010, Australia

We present a miniaturized, millimeter-scale dark-field condenser fabricated using femtosecond two-photon polymerization 3D printing. The device combines an annular absorbing aperture and a high numerical aperture lens on opposite sides of a glass substrate to enable oblique illumination for dark-field imaging. This compact condenser achieves strong contrast enhancement without bulky optics. We demonstrate its performance on USAF 1951 resolution targets, biological samples, and gold nanodisks below 300 nm, which remain invisible under collimated illumination. Our results pave the way for fully 3D-printed, cost-effective dark-field microscopy systems for applications in biology, medicine, and lab-on-chip devices.

Q 77.3 Fri 15:00 P 2

Interferometric wavefront characterization of 3D printed microlens singlets and doublets — •Yanqiu Zhao[1], Chris-Peter Winkler[1], Leander Siegle[1], Simon Thiele[2], and Harald Giessen[1] — [1]4th Physics Institute, Stuttgart, Germany — [2]Printoptix GmbH, Stuttgart, Germany

Femtosecond 3D printing allows for accurate fabrication of microoptics from diameters around 50 micrometers to millimeter scales. Characterizing the shape of printed singlet and doublet lenses is essential to quantify surface deviations caused by polymer shrinkage.

Confocal surface profiling allows z-deviation measurements down to 2 nanometers but loses accuracy on strongly curved surfacesand cannot reliably capture all surfaces or post lengths in compound lenses.

Therefore, we implement a lateral shear interferometer to actually measure the wavefront passing through the 3D printed microlenses, capturing both surface errors as well as refractive index variations from polymer density changes.

Combining confocal profiling with iterative wavefront interferometry, we demonstrate Strehl ratios above 0.97 with RMS wavefront errors around lambda/35 for singlets of over 600 micrometers diameter. For 3D printed doublets, we achieve Strehl ratios above 0.95 with RMS wavefront errors around lambda/28. Residual spherical aberrations are below lambda/100; residual coma and astigmatism values range around lambda/45.

This approach proves that 3D printed microlenses can compete with the best classically manufactured glass lenses up to a certain diameter.

Q 77.4 Fri 15:15 P 2

Characterization of thermodynamic properties of photoresist for 3D printing — •Fernando Lopez-Rodriguez, Robert Horvat, Leander Siegle, and Harald Giessen — 4th Physics Institute and Research Center SCoPE, University of Stuttgart, Pfaffenwaldring 57, 70569 Stuttgart, Germany

3D printing by two-photon polymerization for fabrication of micro-optical components is a widely used and a constantly developing field. The broad range of applications is continuously increasing, as 3D printing is adopted in areas from basic and applied science to manufacturing, quantum technologies, and bio-medical applications. Given the broad field of applications, optical and mechanical material properties, are of high interest. The thermal expansion coefficient alpha(T) and the refractive index n(T) are not known for most photoresists, especially at liquid helium temperatures, which are crucial for quantum applications. In our work, we present a micro-sized, on-fibre dilatometer device based on a 3D-printed Fabry-Pérot interferometer to measure the aforementioned properties over a large temperature range.

Q 77.5 Fri 15:30 P 2

Interferometric Measurements and Interative Metrology for the Shape Correction of 3D-Printed Microoptics — •Chris-Peter Winkler, Yanqiu Zhao, Leander Siegle, and Harald Giessen — 4th Physics Institute and Research Center SCoPE, University of Stuttgart, Pfaffenwaldring 57, 70569 Stuttgart, Germany

We present an interferometric measurement and optimization approach for 3D-printed aspherical singlet and doublet micro-optics fabricated by grayscale lithography. The transmitted wavefront is measured using a lateral shear interferometer, allowing us to reconstruct the corresponding surface height profile of the printed lens, including contributions from surface deviations due to shrinkage and refractive-index modulations arising from density variations in the polymer. The re-

constructed wavefront is decomposed into the first 20 Zernike modes using a least-squares fit to identify the dominant aberrations and filter high-frequency noise. Based on this information, the lens height profile is iteratively corrected. Starting from an initial 0.8 λ spherical aberration, we achieve a Strehl ratio of 0.95 after a single optimization iteration for an aspheric singlet lens with 630 mum diameter

Q 77.6 Fri 15:45 P 2

Direct laser writing of in-volume diffractive optical elements with high speed and high resolution — Christian Ingenhag, Sebastian Stein, Aaron Schüller-Ruhl, and •Robert Fleischhaker — FH Aachen - University of Applied Sciences, Aachen, Germany

We report on a fast, high-resolution scheme to fabricate in-volume diffractive optical elements (DOEs) in fused silica by combining galvanometric beam scanning with a 0.4 NA microscope objective and a 1 ps laser. By exploiting nonlinear absorption and optimizing pulse energy for single-pulse writing, we achieve highly localized refractive-index modifications ($\Delta n \approx 5 \cdot 10^{-2}$) and feature sizes below the nominal focal spot. A layer-stacking scheme in z produces multi-level phase masks: examples are a 4-level, 250x250 px DOE with 2 μm pixels and a 10-level, 416x416 px DOE with 1.2 μm pixels. Phase-contrast microscopy verifies the written phase profiles, which closely match theoretical designs. Optical tests at 532 nm reproduce target intensity patterns with high fidelity (overlap > 80% against the computed discretized mask in a selected region and > 66% versus the original target). Rapid fabrication times (60 s for the 4-level device, 8-9 min for the high-resolution DOE) improve the trade-off between quality and speed toward practical applications.

Q 77.7 Fri 16:00 P 2

Fiber-based femtosecond 3D printing — •Anton Hellstern[1], Claudia Imiolczyk[1], Pavel Ruchka[1], Marco Wende[2], Theresa Kühn[3], Moritz Flöss[1], Michael Heymann[3], Andrea Toulouse[2], and Harald Giessen[1] — [1]4th Physics Institute, University of Stuttgart, Germany — [2]Institute of Applied Optics, University of Stuttgart, Germany — [3]Institute of Biomaterials and Biomolecular Systems, University of Stuttgart, Germany

Ultrashort laser pulses are often used in medical applications, for instance for soft-tissue surgeries. However, the progress on using such laser pulses for additive manufacturing of tissue is rather marginal so far. Therefore, we aim to realize an endoscopic fiber-based femtosecond 3D printer to minimally invasively surgically repair organ damage on a micrometer scale. For this, high peak power femtosecond laser pulses are required, in order to 3D print the desired geometries using two-photon-lithography. By combining a grating compressor, a single-mode fiber, and suitable 3D printed microobjetives directly on the fiber tip, we achieve sub picosecond pulse durations which are able to polymerize both commercial photopolymers as well as bioinks. We report on dose tests, the optimization of printing speed, laser power, pulse compression ratio, and pulse duration. We demonstrate cell colonization of triply periodic minimal surface structures that represent scaffolds by printing 3D honeycombs and seeding them with living fibroblasts. This direct printing of cell scaffolds by endoscopic 3D printing will allow for endoscopic printing of bone tissue inside the body in the future.

Q 78: Quantum Optics and Control III

Time: Friday 14:30–16:15 Location: P 3

Q 78.1 Fri 14:30 P 3

Deciding finiteness of bosonic dynamics — •Tim Heib — Institute for Quantum Computing Analytics (PGI-12), Forschungszentrum Jülich, 52425 Jülich, Germany — Theoretical Physics, Universität des Saarlandes, 66123 Saarbrücken, Germany

Determining the exact dynamics of a given system is paramount in most areas of physics, especially in quantum mechanics. A well-known method for systematically solving these dynamics by factorizing the time-evolution operator into a finite product of exponentials is the Wei-Norman method.

Recently, a new approach has been proposed to investigate the classes of Hamiltonians for which this method is applicable. This involves analyzing the dimensionality of Hamiltonian Lie algebras by appropriately characterizing their generating terms. In our work, we generalize previous results by significantly extending their applicability to a broader class of physically relevant bosonic Hamiltonians. We reduce the complexity of verifying finiteness conditions from quadratic to linear, and we also introduce a visual algorithm to implement the corresponding procedure. Furthermore, we identify a universal Lie algebraic structure encompassing all finite-dimensional algebras within this framework. Our contributions represent a substantial step toward a comprehensive classification of Hamiltonian Lie algebras, with potential impact for practical applications in quantum technologies.

Q 78.2 Fri 14:45 P 3

Optimal Quantum States for Frequency Estimation Limited by Spontaneous Emission — •Marius Burgath[1,2] and Klemens Hammerer[2,1] — [1]Institut für Theoretische Physik, Leibniz Universität Hannover, Germany — [2]Institut für Theoretische Physik, Universität Innsbruck, Austria

We investigate ultimate bounds for frequency estimation with an ensemble of qubits subject to local spontaneous decay. For that purpose, a numerical maximization of the quantum Fisher information (QFI) over the initial state of the ensemble is carried out. For different numbers N of qubits, the QFI is maximized by very different state classes. In the regime of small N, unbalanced GHZ states with a correlated measurement and a nonlinear estimator perform close to optimal. Above a critical number of qubits, the QFI can be maximized by spin Gottesman-Kitaev-Preskill (Spin-GKP) states, which are the compact phase space analogues of the GKP states known from quantum error correction with a harmonic oscillator. The Spin-GKP states show a comb structure in phase space, and the performance of different phase space lattices is investigated. Spin-GKP-like states can also be created with a simple gate sequence. Two one-axis twisting gates and a rotation can be used to create Spin-GKP-like structures around the equator of the Bloch sphere to reach QFI values close to the ultimate bounds.

Q 78.3 Fri 15:00 P 3

Density matrx estimation of multi-mode quantum states from incomplete homodyne data — •Isabell Mischke[1], Carlos Lopetegui[2], Bastien Oriot[2], Mattia Walschaers[2], Valentina Parigi[2], and Tim J. Bartley[1,3] — [1]Department of Physics, Paderborn University, Warburger Str. 100, 33098 Paderborn, Germany — [2]Laboratoire Kastler Brossel, Sorbonne Université, CNRS, ENS-PSL Research University, Collège de France, 4 place Jussieu, F-75252, Paris, France — [3]Institue for Photonic Quantum Systems (PhoQS), Paderborn UNiversity, Warburger Str. 100, 33098 Paderborn, Germany

Homodyne tomography is an experimental procedure to characterize for instance non-classical states as it allows us to determine the state*s statistical operator. The maximum likelihood estimation (MLE) is one possibility to recreate the density matrix from the experimental homodyne quadrature data by finding the most-likely matrix that could have produced the data. The reconstruction itself is a computationally demanding task with exponential scaling for an ascending number of modes. More degrees of freedom become increasingly relevant when looking at highly entangled systems such as cluster states.

We investigate whether it is possible to completely identify the density matrix of a multi-mode state when only a subset of modes is experimentally accessible. With a semidefinite programming approach, we are working towards the approximation of the density matrix by reducing the necessary computational time compared to the analysis of the data of the whole multi-mode state. In the future this method might enable the reconstruction of states with more than four modes.

Q 78.4 Fri 15:15 P 3

Revisiting the fully quantum approach to twisted photons' propagation in atmospheric turbulence — •Tim Ehret, Vyacheslav Shatokhin, and Andreas Buchleitner — Physikalisches Institut, Universität Freiburg, Hermann-Herder Straße 3, 79104 Freiburg

Propagation of photonic spatial modes carrying orbital angular momentum (OAM) through a turbulent atmosphere is an active research area that is important from the fundamental point of view, as well as for applications. A standard approach to account for atmospheric effects on spatial modes is based on the stochastic parabolic equation and the numerical multiple phase screens method derived therefrom. Notwithstanding the success of these approaches, a fully quantum treatment of the propagation of photons through turbulence taking full advantage of the open quantum system toolbox will be highly desirable. However, until now this problem has remained essentially unsolved. In the present contribution, we derive a quantum master equation for the ensemble-averaged density matrix of twisted photons that are phase-distorted by turbulence, show its equivalence to the master equation postulated by F. S. Roux [1], and present some preliminary numerical results. We also compare our results to state of the art of the research field.

[1] Filippus S. Roux, The Lindblad equation for the decay of entanglement due to atmospheric scintillation, Journal of Physics A: Mathematical and Theoretical 47.19, (2014), DOI: 10.1088/1751-8113/47/19/195302

Q 78.5 Fri 15:30 P 3

Spectral signatures of dissipative quantum chaos induced by structured internal degrees of freedom — •Morgan Berkane, Gabriel Dufour, and Andreas Buchleitner — Physikalisches Institut, Albert-Ludwigs-Universität Freiburg, Hermann-Herder-Straße 3, 79104, Freiburg, Germany

Chaos plays a central role in the coherence properties of many-particle quantum systems. In particular, decoherence arises when the internal degrees of freedom of the particles are not exactly identical and become (partially) distinguishable. In this work, we study the emergence of dissipative quantum chaos in a two-level system that is non-chaotic in isolation but coupled to a set of structured internal modes. We examine how chaotic internal modes degrade Hong-Ou-Mandel interference and thus generate particle distinguishability. Our results demonstrate that spectral chaos in inaccessible internal degrees of freedom can leave measurable traces in open quantum dynamics and quantum interference experiments.

Q 78.6 Fri 15:45 P 3

Quantized helicity in optical media — Neel Mackinnon[1], •Jörg Götte[1,2], Stephen Barnett[1], and Niclas Westerberg[1] — [1]University of Glasgow, University Avenue, Glasgow G12 8QQ, United Kingdom — [2]Max-Planck-Institut für Physik komplexer Systeme, Nöthnitzer Str. 38, 01187 Dresden, Germany

We present a novel approach to defining optical helicity in dispersive media that resolves the fundamental incompatibility between duality transformations and linear constitutive relations. By treating electromagnetic and matter degrees of freedom equally, we derive a helicity density that explicitly includes contributions from polarization and magnetization fields. Our formalism, based on duality transformation of vector potentials and matter fields, naturally expresses helicity in terms of polariton excitations. In dual-symmetric media, each circularly polarised polariton carries helicity equal to total energy density divided by frequency, generalising the free-space result. For arbitrary media, single-polariton states exhibit wave-vector-dependent helicity, reflecting different electric and magnetic responses. Remarkably, when helicity is not conserved, superpositions of polariton branches exhibit temporal oscillations analogous to neutrino oscillations. States initially prepared in helicity eigenstates evolve with time-dependent helicity, oscillating at frequency differences between polariton branches. Unlike previous approaches, our definition naturally extends to inhomogeneous, lossy, chiral, and nonreciprocal media, providing a unified framework for understanding helicity transfer in light-matter interactions and chiroptical effects.

Q 78.7 Fri 16:00 P 3

Distinguishability-induced many-body decoherence — •Christoph Dittel[1,2,3,4] and Andreas Buchleitner[1,2] — [1]Physikalisches Institut, Albert-Ludwigs-Universität, Hermann-Herder-Straße 3, 79104 Freiburg, Germany — [2]EUCOR Centre for Quantum Science and Quantum Computing, Albert-Ludwigs-Universität Freiburg, Hermann-Herder-Straße 3, 79104 Freiburg, Germany — [3]Freiburg Institute for Advanced Studies, Albert-Ludwigs-Universität Freiburg, Albertstraße 19, 79104 Freiburg, Germany — [4]Department of Physics, Lund University, Box 118, 221 00 Lund, Sweden

We show that many-body interference phenomena are exponentially suppressed in the particle number, if the identical quantum objects brought to interference acquire a finite level of distinguishability through statistical mixing of some internal, unobserved degrees of freedom. We discuss consequences for cold atom and photonic circuitry experiments.

Q 79: Cavity QED and QED III

Time: Friday 14:30–16:30 Location: P 4

Q 79.1 Fri 14:30 P 4

Heat transport between nonreciprocal media — Nico Strauss, •Omar Jesus Franca Santiago, and Stefan Yoshi Buhmann — Institute of Physics, University of Kassel, Germany

The second law of thermodynamics dictates that heat flows from warm to cold objects, thereby providing a direction of time [1]. In the optics of nonreciprocal media [2], an arrow of time is alternatively provided by the observation that optical paths cannot be reversed. How are these two notions compatible at the level of quantum electro- dynamics? In order to answer this question, we analyse the near-field heat transfer in a three-layer system constituted by nonreciprocal media with special focus on three-dimensional topological insulators, which break time-reversal symmetry. We investigate the impact of these materials on the heat transfer.

References

[1] Volokitin, A. I.; Persson, B. N. J. Rev. Mod. Phys. 4, 79 (2007).
[2] S. Y. Buhmann et al., New J. Phys. 14, 083034 (2012).
[3] Nico Strauß, Heat transfer in macroscopic electrodynamics. Doctoral Dissertation, University Kassel, 2025.

Q 79.2 Fri 14:45 P 4

Noise-protected state transfer between distant nodes in a quantum network — •Syeda Aliya Batool[1], Iñigo Arrazola[2], and Peter Rabl[1] — [1]Walther-Meißner-Institut, 85748 Garching, Germany — [2]Institute of Theoretical Physics-IFT, Madrid, Spain

Low-frequency noise represents a major source of decoherence in cavity QED systems, significantly limiting the fidelity of quantum state transfer and, consequently, the reliability of long-distance quantum communication protocols. To address this challenge, we investigate two complementary noise-mitigation strategies: continuous dynamical decoupling, which implements a continuous spin-echo effect through strong qubit driving, and pulsed dynamical decoupling, which applies sequences of control pulses to suppress low-frequency fluctuations. These techniques target different experimental regimes, and together they offer a universal solution for mitigating low-frequency noise across a wide range of system parameters. We analyze their effectiveness, demonstrating that they can significantly enhance the robustness of qubit-photon interfaces while preserving coherent photon-mediated state transfer. Our results provide practical guidance for implementing noise-resilient qubit-photon interfaces, laying a foundation for secure and high-fidelity quantum information transfer in long-distance quantum networks.

Q 79.3 Fri 15:00 P 4

Quantum metasurfaces as probes of vacuum particle content — •Germain Tobar[1], Joshua Foo[2], Sofia Qvarfort[3], Fabio Costa[3], Rivka Bekenstein[4], and Magdalena Zych[1] — [1]Department of Physics, Stockholm University, SE-106 91 Stockholm, Sweden — [2]Department of Physics and Astronomy, University of Waterloo, Waterloo, Ontario, Canada, N2L 3G1 — [3]Nordita, KTH Royal Institute of Technology and Stockholm University, Hannes Alfvens vag 12, SE-114 19 Stockholm, Sweden — [4]Racah Institute of Physics, The Hebrew University of Jerusalem, Jerusalem 91904, Israel

The quantum vacuum of the electromagnetic field contains spatially localised particle content. We propose to probe this content in the non-perturbative regime of boundary-condition changes using a quantum mirror - a two-dimensional sub-wavelength atomic array dividing a photonic cavity. Its reflectivity is quantum-controlled by a single Ry-

dberg atom, creating coherent superpositions of transmissive and reflective states. Unlike parametric dynamical-Casimir approaches, this platform enables boundary changes that non-perturbatively alter the cavity-mode structure, directly coupling to the particle content of the vacuum. This opens an experimental route to observing superposed Dirchtlet boundary conditions, superpositions of particle creation effects and the dynamical casimir effect with highly non-perturbative boundary condition changes.

Q 79.4 Fri 15:15 P 4

Perfect Quantum State Transfer in a Dispersion-Engineered Waveguide — Zeyu Kuang, •Oliver Diekmann, Lorenz Fischer, Stefan Rotter, and Carlos Gonzalez-Ballestero — Institute for Theoretical Physics, TU Wien, Vienna A-1040, Austria

Faithful transfer of quantum states between distant nodes is a cornerstone of quantum networks, yet even the simplest setups such as two qubits weakly coupled to a waveguide suffer from fundamental efficiency limits related to the temporal shape of the emitted photon. I will present an approach that circumvents this limitation by directly engineering the waveguide dispersion. In particular, I will show how a tailored dispersion profile can reshape the photons wavepacket into the optimal time-reversed form, enabling faithful transfer without external control fields. I will discuss how to design the dispersion relation at different node distances and achieve robustness to variations of these distances.

Q 79.5 Fri 15:30 P 4

Casimir Control: A new Mechanism for Cavity Quantum Materials — Ola Carlsson[1,2], Sambuddha Chattopadhyay[1], Jonathan B. Curtis[1], •Frieder Lindel[1,3], Lorenzo Graziotto[3,4], Jerome Faist[3,4], and Eugene Demler[1] — [1]Institute for Theoretical Physics, ETH Zürich, Zürich 8093, Switzerland — [2]Department of Physics and Arnold Sommerfeld Center for Theoretical Physics (ASC), Ludwig-Maximilians-Universität München, Theresienstr. 37, D-80333 München, Germany — [3]Quantum Center, ETH Zürich, Zürich 8093, Switzerland — [4]Institute of Quantum Electronics, ETH Zürich, Zürich 8093, Switzerland

External classical radiation can control properties of quantum materials. Recently, an alternative has been proposed, in which the external driving is replaced by the quantized modes of a dark cavity.

In my talk, we will discuss Casimir control [1] as a new mechanism for cavity control of electronic nematic order in Fermi liquids, where different electronic order orientations are often energetically degenerate. We will find that the zero-point energy of the electromagnetic continuum, the Casimir energy, depends on the properties of the material system. This can be exploited to stabilize particular orientations of the nematic order. The experimental feasibility will be illustrated using the example of a quantum Hall stripe system [2].

[1] O. Carlsson et al., preprint at arXiv:2510.05088 (2025).
[2] L. Graziotto et al., preprint at arXiv:2502.15490 (2025).

Q 79.6 Fri 15:45 P 4

Casimir forces for nonreciprocal and chiral materials — •Aaron Laszlo Nyerges, Fabian Spallek, and Stefan Yoshi Buhmann — Universität Kassel

The Casimir effect, a manifestation of quantum vacuum fluctuations, remains a vibrant area of research since its prediction in 1948 [1]. Macroscopic Quantum Electrodynamics (QED) provides a foundational framework for studies of Casimir forces in systems with simple geometries and allows for the description of diverse magnetoelectric media with unique properties [2]. In this work, we extend the established solutions for planar multilayer systems of perfectly conducting plates to incorporate generalized material properties. We specifically investigate the Casimir forces generated between plates composed of nonreciprocal media [3], where the Onsager reciprocity relations are violated, and chiral materials with broken parity symmetry. We describe these different media properties on the level of the reflection and transmission coefficients of the material. Our goal is to find a generalized framework to unify these nontrivial electromagnetic properties and to study whether they introduce unique signatures into the Casimir force.

[1] Casimir, H. B. G.: On the attraction between two perfectly conducting plates, Proc. K. Ned. Akad. Wet. 51, 793 (1948). [2] Buhmann, S. Y.: Dispersion Forces I, (Springer, Berlin Heidelberg, 2012). [3] Rode, S., Bennett, R., and Buhmann, S. Y.: Casimir effect for perfect electromagnetic conductors (PEMCs), New. J. Phys. New J. Phys. 20, 043024 (2018).

Q 79.7 Fri 16:00 P 4

Entanglement and pair production in intense electromagnetic fields — Suo Tang[1], Barry Dillon[2], and •Ben King[3] — [1]College of Physics and Optoelectronic Engineering, Ocean University of China, Qingdao, Shandong 266100, China — [2]ISRC, Ulster University, Derry BT48 7JL, UK — [3]Centre for Mathematical Sciences, University of Plymouth, PL4 8AA, UK

We investigate the spin correlations between electron-positron pairs created from a photon when it scatters in a high-intensity laser pulse via the nonlinear Breit-Wheeler process. We find that the spin states of the generated electron-positron pair can exhibit strong entanglement, with the degree being sensitive to the photon energy, laser intensity, and the relative polarization of the photon and laser pulse. Photons with a high degree of polarisation can create strongly entangled pairs even in the intermediate intensity (non-perturbative) regime. We find that if the photons are provided by a Compton source, strongly spin-entangled electron-positron pairs can be generated with technology available today.

Q 79.8 Fri 16:15 P 4

The discovered adequate structure of space provides a foundation of quantum physics — •Hans-Otto Carmesin — Universität Bremen, Fachbereich 1, Postfach 330440, 28334 Bremen — Studienseminar Stade, Bahnhofstr. 5, 21682 Stade — Gymnasium Athenaeum, Harsefelder Straße 40, 21680 Stade

The International Astronomical Union (IAU) proclaimed the problem to find an adequate coordinate system (ACS) of space and time in nature. This problem is solved here: For each point P in the universe, a measurement procedure for the ACS, the existence and the uniqueness of the velocity of the ACS, and the velocity zero of the ACS relative to the gravitational field are derived. As a consequence, the universal zero of the kinematic time difference and of the kinetic energy are derived. For homogeneous space, indivisible volume portions in nature are derived. Moreover, it is shown that homogeneous space is a stochastic average of indivisible volume portions in nature. Therefrom, the dynamics of these volume portions and the quantum postulates are derived. For the derived theory, successful tests are presented, predictions are derived, and experimental tests are proposed.

Carmesin, H.-O. (2025): On the Dynamics of Time, Space and Quanta. Berlin: Verlag Dr. Köster. Carmesin, H.-O. (2021): Quanta of Spacetime Explain Observations, Dark Energy, Graviton and Nonlocality. Berlin: Verlag Dr. Köster.

Q 80: Quantum Technologies – Color Centers III

Time: Friday 14:30–16:15 Location: P 5

Q 80.1 Fri 14:30 P 5

Spectral diffusion and spin signatures of quantum emitters in hexagonal Boron Nitride — •Alexander Pachl[1], Sajedeh Shahbazi[1], and Alexander Kubanek[1,2] — [1]1Institut for Quantum Optics, University Ulm, 89081 Ulm, Germany — [2]Center for Integrated Quantum Science and Technology (IQst), Ulm University, 89081 Ulm, Germany

Single-photon emitters hosted in hexagonal boron nitride (hBN) are, due to their bright and narrow zero-phonon lines (ZPLs) and their two-dimensional host material, promising candidates for integration into upcoming quantum optical technologies. Mechanically decoupled emitters have even shown Fourier-transform-limited linewidths up to room temperature [1,2]. However, these emitters typically suffer from fast spectral diffusion and have so far not shown any spin signatures. In our most recent work, we address these limitations and report observed spin signatures together with an investigation of the fast sprecral diffusion properties.

[1] A. Dietrich et al., Physical Review B, Vol. 98 (2018)
[2] A. Dietrich et al., Physical Review B, Vol. 101 (2020)

Q 80.2 Fri 14:45 P 5

Electron spin-1/2 mediated nuclear-spin entanglement in diamond — •Marco Klotz, Andreas Tangemann, David Opferkuch, and Alexander Kubanek — Institute for Quantum Optics, University Ulm, Germany

Quantum networks will rely on photons entangled to robust, local quantum registers for computation and error correction. We demonstrate control of and entanglement in a fully connected three-qubit 13C nuclear spin register in diamond. The register is coupled to a quasi-free electron spin-1/2 of a silicon-vacancy center (SiV). High strain leads to a ground-state splitting of 1.8 THz and decouples the SiVs electron spin from spin-orbit interaction reducing the susceptibility to phonons at 4 Kelvin. We leverage continuously decoupled microwave and direct radio frequency driving to implement a nuclear-spin conditional phase-gate on the electron spin to mediate bipartite entanglement. This approach presents an alternative to dynamically decoupled nuclear spin entanglement, not limited by the electron spin's 1/2 nature, opening up new avenues to an optically-accessible, solid-state quantum register. [1] M. Klotz et al., https://arxiv.org/pdf/2508.05255, (2025) [2] M. Klotz et al., npj Quantum Inf. 11, 91 (2025)

Q 80.3 Fri 15:00 P 5

Detection and control of a nuclear spin register coupled to a spin-1/2 — •Andreas Tangemann[1], Marco Klotz[1], David Opferkuch[1,2], and Alexander Kubanek[1,2] — [1]Institute for Quantum Optics, Ulm University, Albert-Einstein-Allee 11, 89081 Ulm, Germany — [2]Center for Integrated Quantum Science and Technology (IQST), Ulm University, Albert-Einstein-Allee 11, Ulm 89081, Germany

Solid-state spin defects, such as color centers in diamond, are among the most promising candidates for scalable and integrated quantum technologies. In particular, the good optical properties of negatively-charged silicon-vacancy centers (SiV) in diamond, combined with naturally occurring and exceptionally coherent nuclear spins, serve as a building block for quantum networking applications. We demonstrate detection and control of a nuclear spin register coupled to a highly strained SiV at four Kelvin. Moreover, we measured the interconnectivity of the register with spin-echo double resonance.

[1] M. Klotz et al., https://arxiv.org/pdf/2508.05255, (2025)
[2] M. Klotz et al., npj Quantum Inf. 11, 91 (2025)

Q 80.4 Fri 15:15 P 5

High-fidelity gates in a multi-qubit diamond quantum processor — •Margriet van Riggelen, Jiwon Yun, Hendrik Benjamin van Ommen, and Tim Hugo Taminiau — QuTech and Kavli Institute of Nanoscience, Delft University of Technology, Delft, The Netherlands

Solid-state color centers are a promising platform exploring a range of quantum technologies such as distributed quantum computing and quantum communication. Examples using the nitrogen-vacancy center in diamond include the fault-tolerant operation of a logical qubit [1] and the creation of entanglement on a metropolitan scale [2]. To perform quantum error correction in future algorithms, high-quality quantum control will be needed. Recently, a high-fidelity two-qubit gate was demonstrated on an isolated two-qubit system in purified diamond [3]. However, high-fidelity quantum gates for a multiqubit register based on solid-state color centers have so far remained elusive.

Here, we demonstrate high-fidelity control of six nuclear spins surrounding a nitrogen-vacancy center in diamond using the dynamical decoupling radiofrequency gate. We characterize and benchmark the gates using gate set tomography and find an average of 99.18(2)% for the two-qubit gates in the register. We use the characterized gates in a variational quantum eigensolver algorithm to calculate the ground-state energy of molecular hydrogen and lithium hydride.

[1] Stolk, A.J. et al., Sci. Adv. 10 (2024) [2] Abobeih, M.H. et al., Nature 606 (2022) [3] Bartling, H.P. et al., Phys. Rev. App. 23 (2025)

Q 80.5 Fri 15:30 P 5

10-Second Spin Coherence and Near-Lifetime Optical Linewidths in Isotopically Engineered Diamond — •Hendrik Benjamin van Ommen[1], Takashi Yamamoto[1], Kai-Niklas Schymik[1], René Vollmer[2], and Tim Hugo Taminiau[1] — [1]Qutech, Delft University of Technlogy — [2]Netherlands Organisation for Applied Scientific Research (TNO)

Solid-state spin defects are a promising platform for next-generation quantum technologies, but their performance is fundamentally limited by the quality of the host material. Here we present the growth and characterisation of high-purity, isotopically engineered diamond, grown along the <111> axis, hosting NV centres with excellent spin and optical properties [1]. The reduced ^{13}C concentration results in a spin-echo coherence time of 6.8(1) ms, which is extended beyond 10 s by using up to 24000-pulse dynamical decoupling, both record times for solid-state spins. We observe a strong effect from 50 Hz mains noise, which is mitigated using a real-time feedforward scheme. While it has remained difficult to combine isotopic purification with good optical coherence, we observe a homogeneous optical linewidth of 17.8(4) MHz, near the lifetime limit. We investigate the optical coherence in further depth using a recently introduced diffusion measurement scheme [2]. These results show that our high-purity and isotopically engineered diamond is a promising candidate for future defect-centre-based quantum technologies.

[1] van Ommen et al., in preparation;
[2] van de Stolpe et al., npj Quantum Inf 11, 31 (2025)

Q 80.6 Fri 15:45 P 5

Coherent Control of a Coupled Three-Electron Spin Quantum Register in Diamond — •Fabian Müller[1], Tobias Spohn[1], Philipp J. Vetter[1], Timo Joas[1], Samuele Brambilla[1], Florian Ferlemann[2], René Wolters[2], Tommaso Calarco[2], Matthias M. Müller[2], Shinobu Onoda[3], and Fedor Jelezko[1] — [1]Institute for Quantum Optics, Ulm University, D-89081 Ulm, Germany — [2]Peter Grünberg Institute-Quantum Control (PGI-8), Forschungszentrum Jülich GmbH, D-52425 Jülich, Germany — [3]Takasaki Advanced Radiation Research Institute, National Institutes for Quantum Science and Technology (QST), Takasaki, Gunma 370-1292, Japan

High-fidelity gates between coupled electron spins at room temperature were recently demonstrated using molecularly implanted nitrogen-vacancy (NV) centers in diamond. In addition to NV centers, the implantation process can also create dark spins, providing further scalability for the system.

In this work, we characterize a coupled NV–NV pair and a nearby dark spin (a P1 center) that together form a three-electron spin quantum register at room temperature. We demonstrate coherent interactions among all three spins and probe their coherence properties.

Controlling the P1 center at room temperature is challenging due to the strong hyperfine interaction between its electron and nuclear spin. We present methods such as DEER spectroscopy and double-channel PulsePol to address, coherently control, and read out the P1 center using the nearby NV center. Our work expands the scalability of room-temperature electron spin quantum registers in diamond.

Q 80.7 Fri 16:00 P 5

Influence of strain on the metastable state dynamics of silicon vacancy centers in 4H Silicon Carbide — •Maximilian Hollendonner[1], Fedor Hrunski[1], Durga B. R. Dasari[2], Maximilian Schober[3], Michel Bockstedte[3], and Roland Nagy[1] — [1]Friedrich-Alexander University Erlangen-Nürnberg, Institute of Applied Quantum Technologies (AQuT.), Germany — [2]3rd Institute of Physics, ZAQuant, IQST, University of Stuttgart, Germany — [3]Institute for Theoretical Physics, Johannes Kepler University Linz, Austria

Currently color centers in semiconductors are among the most promising platforms for quantum technology. Especially the negatively charged cubic silicon vacancy center (VSi) in 4H silicon carbide (SiC) stands out due to its exceptional spin and optical properties [1] and can be integrated into semiconductor structures [2]. It is therefore an ideal candidate for quantum memory nodes [3,4]. The VSi can exhibit significant strain when integrated into nanophotonic structures. How this influences spin properties is currently not fully understood. For this reason, we developed pulse sequences which allow the measurement of metastable state transition rates [5]. In my talk I will discuss the changed rates and present the underlying physical mechanisms. [1] R. Nagy et al., Nat Commun 10, 1954 (2019) [2] D. Scheller et al., Phys. Rev. Applied 24, 014036 (2025) [3] S. K. Parthasarathy et al., Phys. Rev. Applied 19, 034026 (2023) [4] R. Nagy et al., Appl. Phys. Lett. 118, 144003 (2021) [5] D. Liu et al., npj Quantum Inf 10, 72 (2024)

Q 81: Quantum Communication, Networks, Repeaters, & QKD III

Time: Friday 14:30–16:30 Location: P 10

Q 81.1 Fri 14:30 P 10

Device-independent quantum key distribution in an event-ready atom-photon architecture over 25 km fiber using double frequency conversion — •Jonas Meiers, Christian Haen, Max Bergerhoff, Tobias Bauer, Christoph Becher, and Jürgen Eschner — Universität des Saarlandes, Experimentalphysik, 66123 Saarbrücken, Germany

Quantum cryptographic protocols offer physical security through no-cloning or entanglement. Following the device-independent quantum key distribution protocol of [1], we present our event-ready implementation based on entanglement between a single atom and its emitted photons. The protocol requires four atomic bases and two photonic bases and allows us to create a quantum key with security verification via the Bell parameter. We employ polarization entanglement between a single trapped $^{40}Ca^+$ ion and an emitted photon at 854 nm, generated on the $P_{3/2} \to D_{5/2}$ transition via Raman scattering [2]. The photon is frequency-converted to the telecom band, enabling its transmission over a 25-km-long, polarization-stabilized fiber spool, and afterwards reconverted to 854 nm before state projection. The projected qubits enable key generation after classical post-processing, including error correction and privacy amplification. Future applications include our 15-km-long urban fiber as quantum link, that has already been characterized and demonstrated [3].

[1] R. Schwonnek et al., Nat. Commun. 12, 2880 (2021)
[2] M. Bock et al., Nat. Commun. 9, 1998 (2018)
[3] S. Kucera et al., npj Quantum Inf. 10, 88 (2024)

Q 81.2 Fri 14:45 P 10

Polarization to time-bin conversion for ion-photon entanglement — •Christian Haen[1], Julian Gross-Funk[1,2], Max Bergerhoff[1], Pascal Baumgart[1], Tobias Bauer[1], Christoph Becher[1], and Jürgen Eschner[1] — [1]Universität des Saarlandes, Experimentalphysik, 66123 Saarbrücken, Germany — [2]see below

Conversion between photonic polarization qubits and time-bin qubits enables the creation of hybrid quantum networks using different quantum memory platforms such as ions and color centers, that provide different inherent types of memory-photon entanglement. For large-scale networks, time-bin encoded quantum information is also less susceptible to polarization changes.

Here, we demonstrate the preservation of ion-photon entanglement after conversion from polarization to time-bin qubits using a telecom fiber-based encoding interferometer. We utilize a single $^{40}Ca^+$ ion in a Paul trap as quantum memory to generate photons that are polarization-entangled with the ion. Additionally, we use quantum frequency conversion to 1550 nm, which is the operating wavelength of the qubit converter, enabling low loss transmission over large distance telecom fiber links [1]. A second quantum frequency converter is used to finally return to the ion transition wavelength.

[1] S. Kucera et al., npj Quantum Inf. 10, 88 (2024).

[2] presently at German Aerospace Center (DLR), Institute of Quantum Technologies, 89081 Ulm, Germany

Q 81.3 Fri 15:00 P 10

Progress towards Intercity Quantum Key Distribution with Deterministic Sources — •Joscha Hanel[1], Fabian Klingmann[2], Jingzhong Yang[1], Jipeng Wang[1], Vincent Rehlinger[1], Zenghui Jiang[1], Jialiang Wang[1], Eddy Patrick Rugeramigabo[1], Raphael Joos[3], Michael Jetter[3], Ali Hreibi[4], Ann-Katrin Kniggendorf[4], Simone Luca Portalupi[3], Peter Michler[3], Stefan Kück[4], Tara Liebisch[1], Michael Zopf[1], and Fei Ding[1,5] — [1]Institut für Festkörperphysik, Leibniz Universität Hannover — [2]Fraunhofer-Institut für Photonische Mikrosysteme, Dresden — [3]Institut für Halbleiteroptik und Funktionelle Grenzflächen, IQST and SCoPE, University of Stuttgart — [4]Physikalisch-Technische Bundesanstalt, Braunschweig — [5]Laboratorium für Nano-und Quantenengineering, Leibniz Universität Hannover

We report on the progress toward a deployed QKD system based on a deterministic quantum dot single photon source, and toward its practical operation on the 78 km Niedersachsen Quantum Link connecting Hannover and Braunschweig.

The system employs high-fidelity polarization encoding at a 152 MHz excitation rate and advanced polarization stabilization to maintain low-error performance and generate keys at practical rates. We further develop and implement a remote clock synchronization scheme that leverages the timing information present within the quantum signal. Our findings underline the viability of deterministic quantum emitters for scalable, real world quantum communication applications.

Q 81.4 Fri 15:15 P 10

Stand-alone mobile quantum memory system — •Martin Jutisz[1], Alexander Erl[2,3], Janik Wolters[2,3], Mustafa Gündoğan[1], and Markus Krutzik[1,4] — [1]Humboldt-Universität zu Berlin and CSMB Adlershof, Berlin, Germany — [2]Technische Universität Berlin, Berlin, Germany — [3]Deutsches Zentrum für Luft- und Raumfahrt, Berlin, Germany — [4]Ferdinand-Braun-Institut (FBH), Berlin, Germany

Quantum memories (QMs) are pivotal to many areas of quantum information science, most notably quantum repeaters. Therefore, these devices must be capable of operating in non-laboratory environments, even in space. Warm-vapour QMs are especially appealing for this purpose because of their simplicity and ease of operation.

We will present the implementation and performance analysis of a portable, standalone warm vapour quantum memory system [1]. The memory operates with weak coherent pulses of less than one photon per pulse. We demonstrate the memory's long-term stability over a 28-hour period, including operation in a non-laboratory environment. We also report ongoing progress in miniaturising the memory platform and demonstrating storage of heralded single photons generated via spontaneous parametric down-conversion.

[1] M. Jutisz et al., Phys. Rev. Applied 23, 024045 (2025).

Q 81.5 Fri 15:30 P 10

A Compact Receiver for Polarisation Encoded BB84 Quantum Key Distribution — •Michael Steinberger[1,2], Moritz Birkhold[1,2], Michael Auer[1,2,3], Adomas Baliuka[1,2], Harald Weinfurter[1,2,4], and Lukas Knips[1,2,4] — [1]Ludwig Maximilian University (LMU), Munich, Germany — [2]Munich Center for Quantum Science and Technology (MCQST), Munich, Germany — [3]Universität der Bundeswehr, Neubiberg, Germany — [4]Max Planck Institute of Quantum Optics (MPQ), Garching, Germany

Quantum Key Distribution (QKD) enables the secure exchange of secret keys, by exploiting the laws of quantum mechanics. Free-space optical communication allows for a range of different QKD use-cases, including short ground-to-ground links for urban environments up to key exchange with satellites. Current hardware uses telescopes with complex optics and highly efficient single-photon detection devices. To make QKD suitable for scenarios offering less space and profiting from a higher degree in mobility, our goal is to develop very compact and integrated detection systems for polarization-encoded BB84 QKD. We demonstrate a miniaturized polarisation analysis unit (PAU) on the millimeter scale. To be used with CMOS single photon avalanche detector arrays these concepts - trading in performance - achieve a new level of of scalability and integrability.

Q 81.6 Fri 15:45 P 10

QKD via Nanosatellites - Qube 2 Mission Hardware and Update — •Moritz Birkhold for the QUBE 2 Konsortium-Collaboration — Ludwig Maximilian University (LMU) — Munich Center for Quantum Science and Technology (MCQST)

Since the first proposal of the BB84 protocol in 1984, Quantum Key Distribution (QKD) has progressed from laboratory demonstrations to large-scale deployed fiber-based networks of 2000+ km in China. However, the limited reach of terrestrial links continues to motivate the development of space-based QKD to achieve global coverage. As a first step towards this goal, the QUBE-1 pathfinder mission, launched in 2024 with compact optical payloads but without full QKD capability, has enabled initial quantum experiments in orbit.

Building on the technologies and experience gained from these, the successor mission QUBE-2 now will introduce several major upgrades to enable full QKD operation from a nanosatellite platform. The optical terminal now includes an enlarged 8 cm aperture, improving link performance, while the fully re-engineered optical assembly is hermetically sealable and more reproducible. The QKD electronics supports repetition rates up to 200 MHz, incorporates decoy-state capability,

and can perform all required post-processing tasks. Ground validation demonstrated key exchange with QBER $< 0.5\%$. The payloads have successfully passed testing, are already integrated with the satellite bus and prepared for launch in 2026.

Q 81.7 Fri 16:00 P 10

Narrow-band resonator-enhanced SPDC source for airborne quantum communication — Sheng-Hsuan Huang[1,2], •Thomas Dirmeier[1,2], Hans Dang[1,2], Sebastian Luff[1,2], Martin Fischer[1], Markus Sondermann[1,2], Gerd Leuchs[1,2], and Christoph Marquardt[2,1] — [1]Max Planck Institute for the Science of Light, Staudtstr 2, 91058 Erlangen — [2]Department of Physics, Friedrich-Alexander-Universität Erlangen-Nürnberg, Staudtstr 7/A3, 91058 Erlangen

Long-distance quantum communication networks rely on the ability to faithfully distribute quantum information between different network nodes, which are often considered based on from atomic or ionic systems. Efficient information transfer not only relies on a low-loss quantum channel but also requires sources that generate quantum states which can interact with the atom or ion in question. Whispering gallery mode resonator (WGMR) based SPDC sources have been shown to be highly tunable sources for a variety of quantum states. Their inherent optical bandwidth in the MHz-range making them compatible to atomic and ionic transitions.

As part of the German QuNET initiative, we are employing our WGMR-based source aboard a research aircraft of the German DLR. Together with a ground station by Fraunhofer IOF. We are investigating the coupling of photonic quantum states to a single trapped ion under adverse conditions from an airborne free-space link.

In our presentation, we highlight the challenges of realizing photon-atom-interaction experiments in such a demanding environment.

Q 81.8 Fri 16:15 P 10

Fully Integrated Multifunctional Platform for Secure QKD Using Waveguide-Integrated SNSPDs — •Connor A. Graham-Scott[1,2,3], César Bertoni Ocampo[1,2,3], Janis Averbeck[1,2,3], and Carsten Schuck[1,2,3] — [1]Department for Quantum Technology, University of Münster, Germany — [2]Center for NanoTechnology - CeNTech, Münster, Germany — [3]Center for Soft Nanoscience - SoN, Münster, Germany

Quantum key distribution (QKD) is a central technology for secure quantum communications, yet current implementations are typically limited in scalability and functionality, e.g. lacking capabilities for guaranteeing signal integrity. The challenge is to achieve a compact, fully integrated platform that not only performs QKD but also detects sophisticated eavesdropping attempts and provides redundancy through alternative encryption pathways.

Here, we present a multifunctional, fully integrated system on a single chip combining several functional blocks based on waveguide-integrated superconducting nanowire single-photon detectors (WI-SNSPDs). Our system combines time-bin COW QKD with a 200-ps delay line, intrinsic and statistical photon-number-resolution methods, polarization-independent operation, and the detection of intercept-resend blinding attacks. By leveraging high-efficiency and low-jitter performance of correspondingly configured WI-SNSPDs, the system allows for both high key generation rates and enhanced security, while remaining scalable and suitable for full integration in future quantum communication systems.

Q 82: Matter Wave Interferometry, Metrology, and Fundamental Physics IV

Time: Friday 14:30–16:30 Location: P 11

Q 82.1 Fri 14:30 P 11

Extracting signal from noisy very-long baseline atom interferometers — •Michael Werner and Naceur Gaaloul — Institut für Quantenoptik, Leibniz Universität Hannover, Welfengarten 1, 30167 Hannover, Germany

Light pulse atom interferometers (AIFs) are exquisite highly quan- tum sensors for inertial forces. State-of-the-art AIFs are used to mea- sure the fine-structure constant, or analyze the gravitational field and its spatial and temporal variations to high accuracy. Distinguish- ing between actual signals and noise is a critical challenge, especially when aiming to detect gravitational waves or dark matter in the mid- frequency range. Understanding each noise source in the interfero- metric process is essential for the success of future initiatives. In our study, we examine how various prominent noise sources impact one- dimensional AIFs of different configurations and identify the most sta- ble setups for the example of the VLBAI facility in Hannover

Q 82.2 Fri 14:45 P 11

Simulation Framework for Space-borne Quantum Sensors — •Gina Kleinsteinberg[1], Christian Struckmann[1], Christian Schubert[2], and Naceur Gaaloul[1] — [1]Institute of Quantum Optics, Leibniz University Hannover, Welfengarten 1, 30167 Hannover, Germany — [2]German Aerospace Center (DLR), Institute for Satellite Geodesy and Inertial Sensing, Callinstr. 30b, 30167 Hannover, Germany

Space-borne cold atom interferometers are promising sensors to probe accelerations and rotations at unprecedented levels of sensitivity. To advance the necessary technology readiness level and mature the space-deployment for future missions, technological demonstrators are needed. Among them are embarked testbeds, such as the *BECCAL* project which is planned to be deployed onboard the ISS and the *CARIOQA* mission, a future pathfinder for quantum accelerometry for Earth observation. To derive the experimental requirements and sensor performances, dedicated simulations are needed.

We present a *Python* based simulation framework that generates realistic phase signals for space-borne atom interferometers. This includes simulations of the atom interferometer itself as well as detailed analyses of systematic effects arising from environmental influences. To define the best operational mode of the experimental setup, multi-objective optimisation is used to explore options for balancing the multitude of mission parameters, while simultaneously optimising the sensor performance. We demonstrate the framework's capabilities through applications to the *CARIOQA* and the *BECCAL* project.

Q 82.3 Fri 15:00 P 11

Constraining the Casimir-Polder force via the scanning angle method — •Matthieu Bruneau[1,2], Gabin Routier[1], Etienne De Girolamo[1], Nathalie Fabre[1], Eric Charron[3], Thorsten Emig[4], Gabriel Dutier[1], Quentin Bouton[1], and Naceur Gaaloul[2] — [1]LPL, Université Sorbonne Paris Nord, Vil- letaneuse, France — [2]IQO, Leibniz Universität Hannover, Germany — [3]ISMO, CNRS, Université Paris-Saclay, Orsay, France — [4]LPTMS, CNRS, Université Paris-Saclay, Orsay, France

The Casimir-Polder (C-P) force is a universal atom-surface interaction arising from quantum fluctuations. Dominant at nanometric distances, it is closely linked to possible non-Newtonian gravitational effects. In this work, we model an experiment in which cold atoms are diffracted by a nanostructure, with C-P interactions encoded in the resulting diffraction pattern.

Current experimental sensitivity is limited mainly by the geometry of available nanogratings. To improve precision, we introduce a scanning-angle detection method and examine the influence of several C-P models, from simple van der Waals summations to full QED calculations based on multiple-scattering expansions. This approach enhances sensitivity, paving the way to more accurate characterization of atom-surface interactions and providing tighter constraints on hypothetical deviations from Newtonian gravity.

This work is supported by BMWK DLR funds (50WM2450A QUANTUS-VI).

Q 82.4 Fri 15:15 P 11

Advances in matter-wave interference of metal nanoparticles — •Richard Ferstl[1], Sebastian Pedalino[1], Bruno E. Ramírez-Galindo[1], Klaus Hornberger[2], Stefan Gerlich[1], and Markus Arndt[1] — [1]Faculty of Physics, University of Vienna, Vienna, Austria — [2]Faculty of Physics, University of Duisburg-Essen, Duisburg, Germany

Metal nanoparticles are a promising platform for universal near-field matter-wave interference experiments with scalable masses. Such experiments require innovative methods for beam formation, coherent beam splitters and efficient detectors. Here we present the state of the art in quantum interference experiments based on photodepletion beam splitters using 266 nm deep ultraviolet light gratings. Our experiment confirms the quantum wave nature of massive sodium nanoparticles, establishing the highest macroscopicity in a quantum experiment to date. The observed phase stability and high sensitivity to external forces opens our experimental platform to precision sensing applications, both in the regime of quantum wave and classical ray optics.

Q 82.5 Fri 15:30 P 11

Relativistic effects and their test in atom interferometry — •Christian Niehof, Daniel Derr, and Enno Giese — Technische Universität Darmstadt, Fachbereich Physik, Institut für Angewandte Physik, Schlossgartenstr. 7, D-64289 Darmstadt, Germany

Light-pulse atom interferometry with ultracold atoms enables high-precision experiments with applications ranging from inertial sensing to fundamental physics. Some gravitational-wave and dark-matter detectors are already proposed based on these techniques. However, achieving the required sensitivities demands large spacetime-area interferometers with substantial arm separations. This makes finite light propagation times and related relativistic effects non-negligible [1]. Thus, a consistent phase description must include state-dependent atomic Compton frequencies resulting from internal-state mass defects and gravitational influences on light and atoms. Additionally, resonant operation in accelerating frames requires laser-frequency chirps.

We present a unified framework that incorporates these effects for arbitrary interferometer geometries and diffraction mechanisms. When applied to Mach-Zehnder gravimeters that use either single-photon, Bragg, Raman, or recoilless E1-M1 transitions, our framework yields exact phase expressions under resonant chirping. These expressions show strong suppression of finite-speed-of-light terms and offer a method to remove residual velocity dependence. We also propose an experimentally feasible test of these predictions.

[1] J. Liu et al., Quantum Frontiers **3**, 2 (2024)

Q 82.6 Fri 15:45 P 11

Towards measuring the gravitational influence of a test mass using the Very Long Baseline Atom Interferometry facility. — •Guillermo A. Perez Lobato, Vishu Gupta, Kai C. Grensemann, Klaus H. Zipfel, Ernst M. Rasel, and Dennis Schlippert — Leibniz Universität Hannover, Institut für Quantenoptik

One of the scientific objectives of the Very Long Baseline Atom Interferometry (VLBAI) facility in Hannover is to investigate how gravity affects quantum objects such as macroscopically delocallized atomic wave functions. Using the 10 m baseline we plan to position additional test masses at 15 cm from the atoms. Including and removing the additional test mass will allow us to perform a differential measurement in order to determine the gravitational influence of the test mass on the atomic wave function. For this measurement to be possible, a series of technical requirements have to be met. For example: launching an ultracold sample of atoms with sub-nanokelvin effective energies, and giving the atoms a differential momentum sufficient to macroscopically delocallize the wave function. This contribution focuses on the progress in the facility during the past year, including the prototype system for positioning the masses with mm accuracy, demonstrating atom interferometry, and the plans to achieve the full potential of the facility. These include the progress towards achieving highly delocallized matter waves by the manipulation of rubidium atoms utilizing purely optical potentials for matter wave lensing, and control of the kinematics of the atoms for manipulation with Bragg beam splitting processes and Bloch oscillations for launch.

Q 82.7 Fri 16:00 P 11

Towards matter-wave interferometry of proteins — •Olga Rybakova[1], Josef Reisinger[1], Amal S. Kumar[2], Valentin Köhler[2], Marcel Mayor[2], Stefan Gerlich[1], Philipp Geyer[1], and Markus Arndt[1] — [1]University of Vienna, Faculty of Physics & Vienna Doctoral School of Physics Boltzmangasse 5, 1090 Wien, Austria — [2]University of Basel, Department of Chemistry St. Johanns-Ring 19, 4056 Basel, Switzerland

In recent years, our team has provided experimental evidence for the wave nature of tailored organic molecules with masses up to 25 kDa, as well as for that of vitamins and antibiotic polypeptides. We now aim to step our studies up to a significantly higher level of molecular complexity by enabling matter-wave interference with genuine proteins.

Achieving this goal requires coordinated advances on several technological fronts, including generation of stable, slow, and cold molecular beams, coherent manipulation of complex particles, and, potentially, their detection in a neutral state. In this contribution, we outline our approach toward enabling protein interferometry and present recent progress on implementing a molecular beam splitting mechanism based on specially designed photocleavable tags.

Q 82.8 Fri 16:15 P 11

In-trap Collimation for BEC Interferometry in Space — •Gabriel Müller[1], Timothé Estrampes[1,2], Eric Charron[2], Wolfgang P. Schleich[3], Nicholas P. Bigelow[4], Naceur Gaaloul[1], and the CUAS consortium[4] — [1]Institute of Quantum Optics, Leibniz University Hannover, Germany — [2]Institut des Sciences Moléculaires d'Orsay, Université Paris-Saclay, CNRS, France — [3]Institute of Quantum Optics and Center for Integrated Quantum Science and Technology (IQST), Ulm University, Germany — [4]Department of Physics and Astronomy, University of Rochester, USA

Performing dual-species atom interferometry in space allows for precise tests of Einstein's Equivalence Principle, enhanced in sensitivity by extended interrogation times in weightlessness. The accuracy of such experiments is limited by the expansion energies of the dual-species mixtures as well as their differential CoM control. For the simultaneous preparation of condensed mixtures, we propose an in-trap collimation technique featuring in-situ excitations of collective modes compatible with state-of-the-art atom-chip setups. Employing this technique, we demonstrate the 2D collimation of condensed ^{87}Rb atoms in the Cold Atom Laboratory aboard the International Space Station. By careful characterization of the atom dynamics induced by time-dependent magnetic fields, we reduce the expansion energies and control the CoM release dynamics, enabling the observation of a freely expanding BEC up to 700 ms.

Q 83: Ultra-cold Atoms, Ions and BEC VI (joint session A/Q)

Time: Friday 14:30–16:00 Location: N 1

Q 83.1 Fri 14:30 N 1

High fidelity quantum logic on two trapped-ion qubits without ground-state cooling — Amy Hughes, Raghavendra Srinivas, Clemens Löschnauer, •Hannah Knaack, Roland Matt, Chris Ballance, Maciej Malinowski, Thomas Harty, Tyler Sutherland, and Oxford Ionics team — Oxford Ionics, Oxford, United Kingdom

We introduce the *smooth gate* - a novel entangling gate method for trapped-ion qubits where residual motional errors are adiabatically eliminated by ramping the gate detuning. We combine the power of this technique with the robustness of electronic qubit control [1] to perform two-qubit gates with an estimated error of $< 1 \times 10^{-4}$ without the use of ground-state cooling. We characterise the gate error using a new protocol (inspired by subspace randomised benchmarking [2]) which does not require the use of any single-qubit rotations. We further show that the error remains $< 5 \times 10^{-4}$ for Doppler-cooled ions with gate mode temperatures of up to $\bar{n} = 9.4(3)$. These results show that trapped-ion quantum computers can be operated above the Doppler limit, allowing for significantly faster device operation.

[1] C. M. Löschnauer et al., PRX Quantum 6, 040313 (2025)
[2] C. H. Baldwin et al., Phys. Rev. Research 2, 013317 (2020)

Q 83.2 Fri 14:45 N 1

Hybridization of topological defects and repulsive polarons in a Bose gas — •Taha Alper Yogurt[1], Matthew Eiles[1], Nikolay Yegovtsev[2], and Victor Gurarie[2] — [1]Max Planck Institute for the Physics of Complex Systems Nöthnitzer St. 38 01187 Dresden, Germany — [2]Department of Physics and Center for Theory of Quantum Matter, University of Colorado, Boulder Colorado 80309, USA

The immersion of an impurity in a bosonic medium has enabled systematic exploration of the Bose polaron problem across the entire range of impurity-medium coupling strengths. Both attractive and repulsive polarons arising from inherently attractive impurity-medium interactions, such as those involving Rydberg or ionic impurities in neutral ultracold gases, have been extensively investigated. While the attractive polaron represents the ground state of the many-body impurity-bath system, the nature of the metastable repulsive polaron remains less understood. Here, we present a unified framework for describing both attractive and repulsive polarons in one- and two-dimensional (1D and 2D) Bose gases. By obtaining ground- and excited-state solutions of the Gross-Pitaevskii equation for a finite-range impurity potential in a weakly interacting Bose medium, we demonstrate that repulsive polarons are adiabatically connected to topological defects supported by the condensate. In 2D, these defects correspond to vortices and dark ring solitons, while they manifest as distinct solitonic configurations in 1D. Furthermore, we uncover a crossover between the repulsive and attractive polaron branches as the impurity-bath coupling strength increases.

Q 83.3 Fri 15:00 N 1

Spin-coherent eigenstates in quantum magnets — •Felix Gerken and Thore Posske — University of Hamburg, Hamburg, Germany

At special points in the parameter space of quantum magnets, product states can emerge as eigenstates. For a wide range of one-, two-, and higher-dimensional models, their appearance is connected to phenomena such as spin liquids, anyonic phases, and quantum scars. We provide a unified framework through a complete classification of spin-coherent eigenstates of Heisenberg XXZ Hamiltonians with Dzyaloshinskii-Moriya interaction on general graphs and for arbitrary spin quantum numbers, formulated in terms of Kirchhoff rules for spin supercurrents. We find that these spin-coherent eigenstates not only span a large degenerate subspace, but are also accompanied by additional extensive degeneracy that is linked to exotic condensates, which could be studied in atomic gases and quantum spin lattices.

Q 83.4 Fri 15:15 N 1

High-repetition-rate fermionic quantum gas microscope for quantum simulation — •Robin Groth[1,2], Andreas von Haaren[1,2], Liyang Qiu[1,2], Janet Qesja[1,2], Luca Muscarella[1,2], Titus Franz[1,2], Timon Hilker[3], Immanuel Bloch[1,2,4], and Philipp Preiss[1,2,4] — [1]Max Planck Institute of Quantum Optics, Garching — [2]Munich Center for Quantum Science and Technology — [3]University of Strathclyde, Glasgow — [4]Ludwig Maximilian University of Munich

Fermionic quantum simulators provide a powerful platform for exploring the physics of high-temperature superconductivity, topological phases, and many-body dynamics - challenges that persist even with the advent of qubit-based quantum computing. Here, we present a high-repetition-rate fermionic quantum gas microscope optimized for rapid data acquisition. Fast cycle times below 4 seconds are achieved through high-power optical traps, rapid evaporative cooling, and efficient spin-resolved fluorescence imaging. These fast experimental cycles enable the collection of sufficient statistics to measure higher-order spin correlations, opening the door to systematic exploration of the phase diagram of the doped Fermi-Hubbard model. Looking ahead, planned upgrades to the apparatus will incorporate site-resolved addressing for precise single-particle control, enabling the investigation of quantum-information-processing schemes within this fermionic platform.

Q 83.5 Fri 15:30 N 1

Simulating the Fermi Hubbard model with a quantum gas microscope — •Luca Muscarella[1,2], Andreas von Haaren[1,2], Robin Groth[1,2], Janet Qesja[1,2], Liyang Qiu[1,2], Ino Ahrens[1,2], Titus Franz[1,2], Timon Hilker[3], Philipp Preiss[1,2], and Immanuel Bloch[1,2,4] — [1]Max-Planck Institute of Quantum Optics — [2]Munich Center for Quantum Science and Technology — [3]University of Strathclyde, Glasgow — [4]Ludwig Maximilian University Munich

Ultracold fermionic systems have emerged as a leading platform for studying strongly correlated quantum matter, offering direct access to regimes that challenge both classical numerics and even qubit-based architectures. Using our newly developed quantum gas microscope, we can create and probe large, low-entropy ensembles of fermions with a short experimental cycle time. Building on this technical capability, we now demonstrate the preparation of a Mott insulator containing over 500 atoms in a square optical lattice. Leveraging a newly implemented programmable lattice with tunable geometry, we aim to probe exotic phases of the doped Fermi-Hubbard model. These measurements will allow systematic exploration of strongly correlated regimes that remain beyond the reach of classical computation.

Q 83.6 Fri 15:45 N 1

Edge localized states in the bosonic SSH model with interaction. — •Anna Posazhennikova and Tara Steinhöfel — Institut für Physik, Universität Greifswald, Greifswald, Germany

We study the bosonic SSH chain with Hubbard on-site interaction, at zero temperature. Since the model can be viewed as a merger of the Bose-Hubbard and Su-Schrieffer-Heeger model, it is expected to undergo both a quantum phase transition from a superfluid Bose-Einstein condensate to a so-called Mott insulator, as well as a topological phase transition when changing dimerization patterns. We find for the topologically nontrivial limit and sufficiently weak interactions, there are edge localized hole states and discuss their origin.

Q 84: Precision Spectroscopy of Atoms and Ions VI (joint session A/Q)

Time: Friday 14:30–15:30 Location: N 3

Q 84.1 Fri 14:30 N 3

Towards a direct g-factor difference measurement of $^{12,14}C^{5+}$ — •Max Anton Gramberg[1], Matthew Bohman[1], Emily Burbach[2], Fabian Heisse[1], Philipp Justus[1], Kristian König[2], Jialin Liu[1], Wilfried Nörtershäuser[2], Sven Sturm[1], and Klaus Blaum[1] — [1]MPIK, Heidelberg — [2]IKP, TU Darmstadt, Darmstadt

ALPHATRAP [1] is a cryogenic Penning-trap apparatus for high-precision measurements. By confining single ions in ultra-stable electromagnetic fields, g-factor determinations at the sub-ppb level are enabled, offering stringent tests of quantum electrodynamics in extreme fields. Even higher precision was reached by measuring the direct g-factor difference of $^{20,22}Ne^{9+}$-ions co-trapped in a Penning trap [2]. In such coherent difference measurements otherwise unavoidable fluctuations of the magnetic field are largely suppressed, allowing to reach sub-ppt accuracy.

The planned measurement of the isotopic shift of the bound electron g-factor between $^{12}C^{5+}$ and $^{14}C^{5+}$ provides a unique opportunity for fundamental atomic physics. The lower nuclear charge Z enables an even more precise prediction by QED calculations and, when combined with the potentially improved precision in our recently upgraded apparatus, can be used to set competitive bounds on scalar dark matter candidates. Conversely, our planned measurement can also be used to extract an ultra precise charge radius difference and so benchmark other radius extraction methods as well as ab-initio nuclear theory.

[1] S. Sturm, *et al. Eur. Phys. J. Spec. Top.* **227**, 1425-1491 (2019). [2] T. Sailer, V. Debierre, *et al. Nature* **606**, 479-483 (2022).

Q 84.2 Fri 14:45 N 3

Atomic Hydrogen beam formation and cryogenic pre-cooling for Project 8 — •Aya El Boustani and Sebastian Böser for the Project 8-Collaboration — Institute of Physics, Johannes Gutenberg University of Mainz, Germany

The Project 8 experiment aims to determine the absolute neutrino mass using Cyclotron Radiation Emission Spectroscopy (CRES) to measure radiation from tritium beta-decay electrons near the spectrum's endpoint, where the neutrino mass effect is most significant. Achieving sensitivity requires an atomic tritium source with well-characterized beam properties. At JGU Mainz, molecular hydrogen serves as a tritium analog and is dissociated in a tungsten capillary heated to 2200 K. The dissociated gas undergoes multi-stage cooling to 8 K, enabling atom trapping while minimizing recombination.

In this study, theoretical modeling and gas-flow simulations investigate the hot source and the first cooling stage. The tungsten capillary is modeled with axial temperature gradients, dissociation kinetics, and pressure profiles; the predicted flux and beam properties are benchmarked against Direct Simulation Monte Carlo results from the SPARTA code for low-density gas flows. In the pre-cooling stage,

the atomic hydrogen beam passes through a bent, cold tube (Accommodator), whose geometry and gas*surface interaction parameters are studied with SPARTA to quantify beam capture, cooling, and recombination. These results guide the design and prototyping of an improved pre-cooling stage, being prepared for testing as part of a future atomic tritium source for Project 8.

Q 84.3 Fri 15:00 N 3

Constraints on Ultra-Light Dark Matter from Networks of Optical Clocks and Cavities — •Luis Hellmich[1,2], Ullrich Schwanke[2], Cigdem Issever[1,2], and Steven Worm[1,2] — [1]Deutsches Elektronen-Synchrotron DESY, Zeuthen, Germany — [2]Humboldt-Universität zu Berlin, Berlin, Germany

Optical atomic clocks and cavities are high precision measurement devices, which are sensitive to variations of the fundamental constants. In this work, we are investigating the sensitivity of networks of optical clocks and cavities to variations of fundamental constants induced by ultra-light dark matter (ULDM). ULDM is expected to oscillate coherently on macroscopic length scales. We are exploring the possibility to detect such oscillations with a network of spatially separated frequency references in two complementary ways. On the one hand, the potential of an optical cavity network is studied. On the other hand, we are analyzing how daily and annual modulations of Earth's movement through the dark matter halo can be used to constrain ULDM models. The proposed setups could detect frequencies in the sub-Hz regime, making it possible to constrain dark matter masses $m \sim 10^{-10} - 10^{-14}$ eV. We present projected limits on the scalar coupling to Standard Model particles for a few benchmark scenarios and compare them to existing constraints from equivalence principle tests.

Q 84.4 Fri 15:15 N 3

Electron Mass, Charge and Sommerfeld FSC — •Manfred Geilhaupt — HS Niederrhein Mönchengladbach

Einstein: Ich wüsste gern, was ein Elektron ist.

**e^2=2*alphah*c*eps0 (no energy!). Question: What must be known else, able to answer Einsteins question? Restmass & Charge must be derived from a principle theory. Results from GR+TD: restmass me(alpha,N) & charge e(alpha). expectation values, both depend on alpha. The r(t)-generating two differential equations - not like Schrödinger but source for mass and charge - can be found using a common Newton Einstein Equation of Motion:

**dP/dt=f1+f2+f3+f4+f5 coming up with 5 internal parts from partial derivation. The second part (f2= m*ddr/ddt) leads to restmass me(alpha,N) being an effective value from the solution m(t) if r(t) is a generating function same for all 5 parts. u(t) is a unit vector possible to rotate (du/dt). The first equation (f1=dr/dt*dm/dt) - if m(t) is known already from part two - leads to charge e(alpha) while alpha is the Sommerfeld FSC:

**alpha=(1/beta)*(1/beta)*1/g44*3/4(1+log(1/3))*(1+log(1/3)) - appears when using r(t) to get m(t) from equation f2. Beta is the Einstein SR parameter while g44 is the well known GR-metric number: while within (e/m)=..1/sqrt(N) here alpha cancels!

alpha represents the continuum part and N the quantum part of nature. So GR+TD predicts QM's quantisation phenomena physically - based on causality and TD principles applied.