Atomic Physics Division
Fachverband Atomphysik (A)

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Overview of Invited Talks and Sessions

(Lecture halls N 1, N 2, N 3, and N 25; Poster Philo 1. OG)

Invited Talks

A 2.1	Mon	11:45–12:15	N 1	**Experimental investigation of strongly interacting quantum fluids of light in rydberg atoms** — •Amar Bellahsene, Tom Bienaimé, Shannon Whitlock
A 6.1	Mon	17:00–17:30	N 1	**Measurement of neon photoemission delays and double-core-hole Auger-Meitner lifetime using Angular Streaking** — •Lars Funke, Sara Savio, Lasse Wülfing, Niclas Wieland, Markus Ilchen, Wolfram Helml
A 8.1	Mon	17:00–17:30	N 3	**Isotope shifts and population dynamics in neutron-rich Mg^+ measured with MIRACLS** — •Konstantin Mohr
A 11.1	Tue	11:00–11:30	N 2	**Dichroic Electron Emission Patterns from Oriented Helium Ions** — •Niclas Wieland, Klaus Bartschat, Filippa Dudda, Michael Meyer, Markus Ilchen
A 12.1	Tue	11:00–11:30	N 3	**Stringent Tests of the Standard Model via High-Precision Measurements at ALPHATRAP** — •Fabian Heisse, Matthew Bohman, Luca Geissler, Anton Gramberg, Philipp Justus, Charlotte König, Ivan Kortunov, Jialin Liu, Jonathan Morgner, Jacob Schrader, Victor Vogt, Stephan Schiller, Sven Sturm, Klaus Blaum
A 13.1	Tue	11:00–11:30	N 25	**Identifications of clock transitions in heavy highly charged ions with high sensitivity to physics beyond the Standard Model** — Nils-Holger Rehbehn, Lakshmi P. Kozhiparambil Sajith, Michael K. Rosner, Charles Cheung, Sergey G. Porsev, Marianna S. Safronova, Samuel M. Brewer, Steven Worm, Dmitry Budker, Thomas Pfeifer, José R. Crespo López-Urrutia, •Hendrik Bekker
A 17.1	Wed	14:30–15:00	N 1	**Three-body dynamics between an ion and two Rydberg states** — •Jennifer Krauter, Maximilian Futterknecht, Óscar Andrey Herrera Sancho, Florian Anschütz, Utzuri Högl Vidal, Moritz Berngruber, Florian Meinert, Robert Löw, Tilman Pfau
A 18.1	Wed	14:30–15:00	N 2	**Cross-process interference in single-cycle electron emission from metal needle tips** — •Anne Herzig, Peter Hommelhoff, Eleftherios Goulielmakis, Thomas Fennel, Lennart Seiffert
A 19.1	Wed	14:30–15:00	N 3	**Enhanced Sensitivity for Electron Affinity Measurements** — •Franziska Maria Maier, Erich Leistenschneider, Lutz Schweikhard, Stephan Malbrunot-Ettenauer
A 27.1	Thu	11:00–11:30	N 1	**Quantum-enabled active matter at the atomic scale** — •Sabrina Burgardt, Julian Fess, Silvia Hiebel, Alexander Guthmann, Aritra K. Mukhopadhyay, Sangyun Lee, Michael te Vrugt, Benno Liebchen, Hartmut Löwen, Raphael Wittkowski, Artur Widera
A 28.1	Thu	11:00–11:30	N 2	**Long-lived giant circular Rydberg atoms at room temperature** — •Fabian Thielemann, Einius Pultinevicius, Aaron Götzelmann, Christian Hölzl, Florian Meinert
A 28.2	Thu	11:30–12:00	N 2	**Dynamical decoupling in a dipolar Rydberg gas** — •Meny Menashes, Eduard Braun, Matthias Lotze, Maharshi Pran Bora, Gerhard Zürn, Matthias Weidemüller

A 29.1	Thu	11:00–11:30	N 3	**An optical clock with entangled trapped $^{40}Ca^+$ ions.** — •Kai Dietze, Lennart Pelzer, Bennet Benny, Fabian Dawel, Mirza A. Ali, Derwell Drapier, Piet O. Schmidt
A 32.1	Thu	14:30–15:00	N 2	**IR-laser induced dressing signatures in helium nanodroplets probed by coherent diffractive imaging** — •Tom von Scheven, Björn Kruse, Thomas Fennel
A 40.1	Fri	11:00–11:30	N 1	**Toolbox for of Rydberg state engineering in trapped ions** — •Robin Thomm, Vinay Shankar, Natalia Kuk, Markus Hennrich
A 41.1	Fri	11:00–11:30	N 2	**State-resolved femtosecond phase control in dense-gas laser-atom interaction enabled by XUV interferometry** — •Lina Hedewig, Carlo Kleine, Yu He, Felix Wieder, Christian Ott, Thomas Pfeifer

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 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

Sessions

A 1.1–1.5	Mon	11:45–13:00	P 2	**Ultracold Matter I – Fermions (joint session Q/A)**
A 2.1–2.3	Mon	11:45–12:45	N 1	**Ultra-cold Plasmas and Rydberg Systems I (joint session A/Q)**
A 3.1–3.5	Mon	11:45–13:00	N 2	**Collisions, Scattering and Correlation Phenomena I (joint session A/MO)**
A 4.1–4.5	Mon	11:45–13:00	N 25	**Highly Charged Ions and their Applications I**
A 5.1–5.8	Mon	17:00–19:00	P 2	**Ultracold Matter II – Bosons (joint session Q/A)**
A 6.1–6.6	Mon	17:00–18:45	N 1	**Attosecond Physics I (joint session A/MO)**
A 7.1–7.8	Mon	17:00–19:00	N 2	**Collisions, Scattering and Correlation Phenomena II (joint session A/MO)**
A 8.1–8.7	Mon	17:00–19:00	N 3	**Precision Spectroscopy of Atoms and Ions I (joint session A/Q)**
A 9.1–9.8	Tue	11:00–13:00	P 2	**Ultracold Matter III – Fermions (joint session Q/A)**
A 10.1–10.8	Tue	11:00–13:00	N 1	**Ultra-cold Atoms, Ions and BEC I (joint session A/Q)**
A 11.1–11.7	Tue	11:00–13:00	N 2	**Atomic Systems in External Fields I**
A 12.1–12.7	Tue	11:00–13:00	N 3	**Precision Spectroscopy of Atoms and Ions II (joint session A/Q)**
A 13.1–13.6	Tue	11:00–12:45	N 25	**Highly Charged Ions and their Applications II**
A 14.1–14.29	Tue	17:00–19:00	Philo 1. OG	**Poster – Precision Spectroscopy of Atoms and Ions (joint session A/Q)**
A 15.1–15.9	Tue	17:00–19:00	Philo 1. OG	**Poster – Highly Charged Ions and their Applications**
A 16.1–16.8	Wed	14:30–16:30	P 2	**Ultracold Matter IV – Bosons, Rydberg Systems, and Others (joint session Q/A)**
A 17.1–17.7	Wed	14:30–16:30	N 1	**Ultra-cold Atoms, Ions and BEC II (joint session A/Q)**
A 18.1–18.6	Wed	14:30–16:15	N 2	**Interaction with Strong or Short Laser Pulses I (joint session A/MO)**
A 19.1–19.7	Wed	14:30–16:30	N 3	**Precision Spectroscopy of Atoms and Ions III (joint session A/Q)**

A 20.1–20.2	Wed	17:00–19:00	Philo 1. OG	**Poster – Atomic Clusters**
A 21.1–21.5	Wed	17:00–19:00	Philo 1. OG	**Poster – Atomic Systems in External Fields**
A 22.1–22.7	Wed	17:00–19:00	Philo 1. OG	**Poster – Attosecond Physics (joint session A/MO)**
A 23.1–23.3	Wed	17:00–19:00	Philo 1. OG	**Poster – Interaction with Strong or Short Laser Pulses (joint session A/MO)**
A 24.1–24.4	Wed	17:00–19:00	Philo 1. OG	**Poster – Interaction with VUV and X-ray Light (joint session A/MO)**
A 25.1–25.8	Wed	17:00–19:00	Philo 1. OG	**Poster – Cluster and Nanoparticles (joint session MO/A)**
A 26.1–26.32	Wed	17:00–19:00	Philo 2. OG	**Poster – Ultracold Matter (joint session Q/A)**
A 27.1–27.7	Thu	11:00–13:00	N 1	**Ultra-cold Atoms, Ions and BEC III (joint session A/Q)**
A 28.1–28.6	Thu	11:00–13:00	N 2	**Ultra-cold Plasmas and Rydberg Systems II (joint session A/Q)**
A 29.1–29.7	Thu	11:00–13:00	N 3	**Precision Spectroscopy of Atoms and Ions IV (joint session A/Q)**
A 30	Thu	13:15–14:00	N 25	**Members' Assembly**
A 31.1–31.8	Thu	14:30–16:30	N 1	**Ultra-cold Atoms, Ions and BEC IV (joint session A/Q)**
A 32.1–32.7	Thu	14:30–16:30	N 2	**Interaction with VUV and X-ray Light I (joint session A/MO)**
A 33.1–33.8	Thu	14:30–16:30	N 3	**Precision Spectroscopy of Atoms and Ions V (joint session A/Q)**
A 34.1–34.3	Thu	14:30–15:15	N 25	**Correlation Phenomena**
A 35.1–35.5	Thu	15:15–16:45	P 105	**Cluster and Nanoparticles (joint session MO/A)**
A 36.1–36.42	Thu	17:00–19:00	Philo 1. OG	**Poster – Ultra-cold Atoms, Ions and BEC (joint session A/Q)**
A 37.1–37.9	Thu	17:00–19:00	Philo 1. OG	**Poster – Ultra-cold Plasmas and Rydberg Systems (joint session A/Q)**
A 38.1–38.3	Thu	17:00–19:00	Philo 1. OG	**Poster – Collisions, Scattering and Correlation Phenomena (joint session A/MO)**
A 39.1–39.15	Thu	17:00–19:00	Philo 2. OG	**Poster – Precision Measurement (joint session Q/A)**
A 40.1–40.7	Fri	11:00–13:00	N 1	**Ultra-cold Atoms, Ions and BEC V (joint session A/Q)**
A 41.1–41.6	Fri	11:00–12:45	N 2	**Interaction with Strong or Short Laser Pulses II**
A 42.1–42.7	Fri	11:00–12:45	N 3	**Atomic Systems in External Fields II**
A 43.1–43.6	Fri	14:30–16:00	N 1	**Ultra-cold Atoms, Ions and BEC VI (joint session A/Q)**
A 44.1–44.4	Fri	14:30–15:30	N 3	**Precision Spectroscopy of Atoms and Ions VI (joint session A/Q)**

Members' Assembly of the Atomic Physics Division

Thursday 13:15–14:00 N 25

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

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

A 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)

A 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.

A 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.

A 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.

A 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.

A 2: Ultra-cold Plasmas and Rydberg Systems I (joint session A/Q)

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

Invited Talk A 2.1 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.

A 2.2 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.

A 2.3 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.

A 3: Collisions, Scattering and Correlation Phenomena I (joint session A/MO)

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

A 3.1 Mon 11:45 N 2

Floquet Resonances in Ultracold Gas Scattering — •Sebastian Eggert, Axel Pelster, and Christoph Dauer — University of Kaiserslautern-Landau (RPTU)

An alternative mechanism of tuning interactions between cold atoms is proposed, which is based on dynamically creating "Floquet bound states" using time-periodic fields. By developing a Floquet-scattering theory we show that sharp Floquet resonances occur at which the effective interaction can be tuned to very large attractive or repulsive values. The resulting predictions explain recent experimental data and provide additional tuning possibilities. Analytic predictions are given for adjusting amplitude, frequency and mean of the applied oscillating field in order to to accurately choose location and width of scattering resonances over a wide range. This paves the road to a versatile toolbox of tailored interactions in setups with multiple species.

A 3.2 Mon 12:00 N 2

Light scattering experiments in dense dipolar gases — •Ishan Varma, Marvin Proske, Rhutwik Sriranga, Dimitra Cristea, and Patrick Windpassinger — Staudingerweg 7, Institute of Physics, JGU Mainz

In ultracold atomic ensembles where interatomic spacing is smaller than the wavelength of scattered light, direct matter-matter coupling through electric and magnetic interactions significantly influence system dynamics, challenging the approximation of atoms as independent emitters. We study the role of magnetic dipole-dipole interactions (DDI) in the cooperative behavior of atomic ensembles using dysprosium, which has the highest ground-state magnetic moment (10 Bohr magnetons).

This talk focusses on the recently performed light scattering experiments in moderately-dense samples of ultracold dysprosium atoms. We study the scattering properties of the sample with respect to frequency detuning from resonance, optical depth, and external magnetic field. A detailed analysis of the fluorescence signal reveals first indications of super- and sub-radiance, which suggest cooperative behavior in the system. In addition, we also discuss the impact of optical dipole trap polarization on atomic lifetime and highlight the recent technical advancements made in vacuum technology and the design of microscope objectives. These developments enable a higher degree of control and accessibility of the atomic sample.

A 3.3 Mon 12:15 N 2

Transport resonances through periodically driven, weakly coupled impurity — •Jan Mathis Giesen, Daniel Weber, and Sebastian Eggert — Physics Department and Research Center OPTIMAS, RPTU University Kaiserslautern-Landau, D-67663 Kaiserslautern, Germany

We consider transport in an optical lattice through quantum well with time periodic driving and apply Floquet theory to calculate tunneling amplitudes. An analytic non-equilibrium solution of the problem is developed which allows the analytic prediction and analysis of the tunneling amplitudes as a function of frequency, driving amplitude, and energy level of the well. One main result is the discovery of a previously unknown resonant switching effect, where a very small driving field can induce perfect transmission. The results are relevant for corresponding setups using ultra-cold gases in optical lattices, photonic waveguides, quantum dots coupled to metallic leads or magnonic systems.

A 3.4 Mon 12:30 N 2

The interplay between single- and two-body interference of photoelectrons — •Fabian Rohrbach[1], Andreas Buchleitner[1,2], and Christoph Dittel[1,2] — [1]Physikalisches Institut, Albert-Ludwigs-Universität Freiburg, 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

We clarify under which conditions fermionic exchange (anti-) symmetry manifests in the energy spectrum of photoelectrons generated by pulsed light interacting with matter, and how such signature can be discriminated against anticorrelations potentially arising from Coulomb repulsion. We demonstrate that photoelectrons emitted from two metal needle tips exhibit pronounced two-body interference fringes, and analyze how these features interplay with interference on the single-electron level, along different pathways in a pump–probe ionization scheme.

A 3.5 Mon 12:45 N 2

Protected quantum gates using qubit doublons in dynamical optical lattices — •Lars Fischer, Yann Kiefer, Zijie Zhu, Samuel Jele, Marius Gächter, Giacomo Bisson, Konrad Viebahn, and Tilman Esslinger — Institute for Quantum Electronics & Quantum Center, ETH Zürich, Otto-Stern-Weg 1, 8093 Zürich

Scalable quantum computation relies on configurable qubit connectivity through system-wide, error-free transport of quantum states. Neutral atoms in optical lattices represent a promising platform for quantum computing, where collisional gates provide a controlled mechanism for quantum logic. Here, we present a purely geometric two-qubit SWAP gate that transiently populates qubit doublon states of fermionic atoms in a dynamical optical lattice. Using atomic spin singlets of fermionic potassium-40, we demonstrate the experimental realisation of this quantum holonomy enabled by doublon states. The gate mechanism is based on a geometric evolution in which dynamical phases are entirely absent, making the mechanism intrinsically robust against fluctuations and inhomogeneities in the confining potentials.

We report a loss-corrected two-qubit SWAP gate fidelity of 99.91(7)%, measured across an ensemble of more than 17,000 atom pairs. Combined with tunable atomic collisions, we realise a universal set of two-qubit gates, paving the way toward large-scale, highly connected quantum processors. Our scheme, based on topological pumping of atoms, establishes the foundation for a fault-tolerant computational platform.

A 4: Highly Charged Ions and their Applications I

Time: Monday 11:45–13:00 Location: N 25

A 4.1 Mon 11:45 N 25

Charge Exchange Mechanisms in Slow Highly Charged Ions Colliding with Gas Targets — •Anju Shaji Nair, Stefan Facsko, and René Heller — Helmholtz-Zentrum Dresden-Rossendorf, Institute of Ion Beam Physics and Materials Research, Bautzner Landstrasse 400, Dresden 01328, Germany

The dynamic charge exchange processes occurring during the interaction of slow, highly charged ions (HCI) with a material surface are the key mechanisms guiding the inelastic processes and material response [1,2]. To isolate and understand these fundamental mechanisms, a clean two-body system is required. For this purpose, gas targets are used, as they provide an intrinsically clean environment that enables the examination of individual collision events and provide insights into the underlying electron transfer dynamics.

In this work, the interaction mechanism of slow Xenon ions having charge states 5+ to 30+ with He and N2 targets is investigated. The experimentally determined single-electron capture cross-sections show a decreasing trend with increasing projectile charge state, indicating a shift in the dominant charge exchange pathways from predominantly single-electron capture to contributions from multiple electron transfer processes.

References:

[1] Niggas, A., Werl, M., Aumayr, F., & Wilhelm, R. A. (2024) J. Phys. B: At. Mol. Opt. Phys. 57(7) 072001

[2] Wilhelm, R. A. (2022) Surf. Sci. Rep. 77(4) 100577

A 4.2 Mon 12:00 N 25

Nuclear Excitation by Electron Capture - Towards a Direct and Unambiguous Detection — •Esther B. Menz for the NEEC-at-GSI-Collaboration — University of Cologne — GSI, Darmstadt

Nuclear excitation by electron capture (NEEC) is a fundamental process that provides a direct interaction between the nucleus and the atomic shell. It is the time-inverse of the well-understood process of internal conversion (IC): an electron is resonantly captured into an atomic bound state and the nucleus is simultaneously excited by the energy made available by the capture. The process is thought to be relevant for plasma and astrophysics and might have useful applications such as producing desirable nuclear isomeric states. Despite significant efforts, no uncontroversial experimental observation of NEEC has yet been reported. A claimed observation by Chiara et al. [1] deviated from theoretical predictions by nine orders of magnitude [2] and could not be independently confirmed in an experiment by Guo et al. [3]. Motivated by successful measurements of dielectronic recombination processes in ion storage rings, we plan to search for NEEC at the ESR storage ring of GSI. Using the ESR electron cooler as a free-electron target provides the distinct advantage of avoiding effects introduced by the solid target in the aforementioned single-pass experiment.

We will present the current status of experiment preparation along with estimations of the expected count and background rates.

[1] C. J. Chiara et al., Nature 554, 216 (2018)

[2] Y. Wu et al., Phys. Rev. Lett. 122, 212501 (2019)

[3] S. Guo et al., Phys. Rev. Lett. 128, 242502 (2022)

A 4.3 Mon 12:15 N 25

Update on the Lsym experimental setup — •Fabian Raab, Maria Pasinetti, Paul Holzenkamp, Sarah Placek, Leonie Marzel, Andreas Thoma, Sangeetha Sasidharan, and Sven Sturm — MPIK, Heidelberg, Germany

Lsym is a new cryogenic Penning trap experiment that intends to test the symmetry of matter and antimatter in the lepton sector. In particular, the experiment will test for differences in mass, charge and g-factor of the positron and electron to achieve the most precise test for a hypothetical CPT violation for leptons so far. In the experiment we detect the particles motional frequencies via image current detectors. To further cool the trapped positron to its ground state of motion, the trap assembly is cooled to about 300 mK, where the trap cavity is largely depleted from black-body photons around the cyclotron frequency of 140 GHz. In this presentation our recent steps towards setting up our detection system as well as an update on the microwave setup, that will be used to counteract heating above the groundstate, will be illustrated.

A 4.4 Mon 12:30 N 25

Positron trapping and current trap design at LSym — •Maria Pasinetti, Fabian Raab, Paul Holzenkamp, Andreas Thoma, Sangeetha Sasidharan, Leonie Marzel, Sarah Placek, and Sven Sturm — MPIK, Heidelberg, Germany

LSym is a new cryogenic Penning trap experiment under development at the Max-Planck-Institut für Kernphysik in Heidelberg. Its goal is a stringent CPT test by comparing matter*antimatter properties through a high-precision measurement of the electron and positron spin precession frequencies. To this end, a single positron and a He+ ion, a proxy for the electron are trapped simultaneously, enabling a decoherence-free comparison. A positron capture technique was successfully tested in December 2024. Positrons from a weak ^{22}Na β^+ source are moderated and converted into positronium in a high Rydberg state, which is then ionized inside the Penning trap, allowing the positron to be retained. The key observable is the difference in the two Larmor frequencies, determined by the charge-to-mass ratios and g-factors of the particles. These frequencies are measured with a dual Ramsey sequence, where we determine the spin projection of each particle non-destructively via the continuous Stern-Gerlach effect in a magnetic bottle. At LSym, spin-state detection occurs in the "AnalysisTrap", a five-electrode Penning trap with a ferromagnetic ring electrode that generates the required gradient. The presentation outlines the positron source concept and the current status of the AnalysisTrap fabrication and assembly.

A 4.5 Mon 12:45 N 25

Hadronic Vacuum Polarization: From functional QCD to Atomic Physics — •Eugen Dizer[1], Zoltán Harman[2], Franz R. Sattler[3], and Jonas Wessely[4] — [1]Institut für Theoretische Physik, Universität Heidelberg, Philosophenweg 12, 69120 Heidelberg, Germany — [2]Max Planck Institute for Nuclear Physics, Saupfercheckweg 1, 69117 Heidelberg, Germany — [3]Fakultät für Physik, Universität Bielefeld, 33615 Bielefeld, Germany — [4]Institut für Theoretische Physik, Justus-Liebig-Universität, Heinrich-Buff-Ring 16, 35392 Giessen, Germany

Hadronic vacuum polarization (HVP) remains a major source of uncertainty in precision tests of the Standard Model, particularly in the muon anomalous magnetic moment a_μ. The persistent discrepancy between data-driven evaluations and lattice QCD, together with recent updates to $g-2$, motivates a deeper investigation of HVP across independent methods. We study the hadronic polarization function $\Pi_{\rm had}(q^2)$ using functional QCD techniques, and compare with state-of-the-art data-driven determinations and lattice calculations.

We propose highly charged ions and muonic atoms as sensitive and experimentally accessible systems for probing HVP at low momentum transfer. Their clean QED structure and tunable energy scales make them an ideal platform for testing effective hadronic contributions. Using an updated effective Uehling potential, we evaluate HVP effects in these systems and assess their potential to clarify the present data–lattice tension.

A 5: Ultracold Matter II – Bosons (joint session Q/A)

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

A 5.1 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 quality. 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.

A 5.2 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).

A 5.3 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.

A 5.4 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)

A 5.5 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).

A 5.6 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.

A 5.7 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.

A 5.8 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.

A 6: Attosecond Physics I (joint session A/MO)

Time: Monday 17:00–18:45 Location: N 1

Invited Talk A 6.1 Mon 17:00 N 1

Measurement of neon photoemission delays and double-core-hole Auger-Meitner lifetime using Angular Streaking — •Lars Funke[1], Sara Savio[1], Lasse Wülfing[1], Niclas Wieland[2], Markus Ilchen[2], and Wolfram Helml[1] — [1]Fakultät Physik, Technische Universität Dortmund, Germany — [2]Institut für Experimentalphysik, Universität Hamburg, Germany

The extreme brightness of X-ray free electron lasers allows probing non-linear processes in atoms and molecules in single-shot measurements. The addition of a temporal reference, e.g. through an Angular Streaking setup, enables the direct measurement of observables previously only accessible indirectly.

Here, we report on a European-XFEL measurement that simultaneously yields relative emission delays for multiple transitions triggered by 990 eV photons in neon. Specifically, we are able to clock 1s, 2s and 2p photoelectrons, single- and double-core-hole Auger-Meitner electrons at the same time, owing to a multi-resolution time-of-flight detector setup covering a broad electron energy range.

A 6.2 Mon 17:30 N 1

Observation of sub-cycle ponderomotive acceleration via near-field-induced low-energy stripes (NILES) — •L. Seiffert[1], J. Heimerl[2], S. Meier[2], A. Herzig[1], F. Lòpez Hoffmann[2], D.M.B. Lesko[2], S. Hillmann[2], S. Wittigschlager[2], T. Weitz[2], T. Fennel[1,3], and P. Hommelhoff[2,4] — [1]Institute of Physics, University of Rostock, Germany — [2]Department of Physics, Friedrich Alexander University Erlangen-Nuremberg, Germany — [3]Department of Life, Light and Matter, University of Rostock, Germany — [4]Faculty of Physics, Ludwig Maximilian University Munich, Germany

Ponderomotive acceleration of electrons in strong fields is typically regarded as a cylce-averaged effect and hence mostly associated with long pulses. However, recently, subcycle sensitivity of the ponderomotive acceleration effect has been reported for electrons injected into the strong near-field gradient of a sharp metal tip by a few-cycle optical waveform [1]. In this talk the recent observation of this effect which manifests in the direct electrons part of carrier-envelope-phase-dependent electron spectra in the form of near-field-induced low-energy stripes (NILES) will be discussed from a theoretical point of view. These stripes allow the tracking of direct and rescattered electron emissions on subcycle timescales and provide access to the electron momentum width at emission.

[1] J. Heimerl at al., Nat. Phys. (2025)

A 6.3 Mon 17:45 N 1

A rigorous and universal approach for highly-oscillatory integrals in attosecond science — •Anne Weber[1], Job Feldbrugge[2], and Emilio Pisanty[1] — [1]Attosecond Quantum Physics Laboratory, King's College London, WC2R2LS London, UK — [2]Higgs Centre for Theoretical Physics, University of Edinburgh, UK

Light-matter interactions within the strong-field regime, such as high-harmonic generation, typically give rise to highly-oscillatory integrals, which are often solved using saddle-point methods. Not only do these methods promise a much faster computation, but they also inform a more intuitive understanding of the process in terms of quantum orbits, as the saddle points correspond to interfering quantum trajectories (think Feynman's path integral formalism). Despite these advantages, a sound understanding of how to apply saddle-point methods to highly-oscillatory integrals in a rigorous way, and with algorithms which work uniformly for arbitrary configurations and laser drivers, remains lacking. This hinders our ability to keep up with state-of-the-art experimental setups which increasingly rely on tightly-controlled laser waveforms. Here, I will introduce the key ideas of Picard-Lefschetz theory – the foundation of all saddle-point methods – and their implementation. Using high-harmonic generation and above-threshold ionisation as examples, I will show how those ideas provide a robust framework for the fast computation of integrals, as well as a widely-applicable algorithm to derive the relevant semiclassical quantum orbits that underlie the physical processes.

A 6.4 Mon 18:00 N 1

Structured light for enhanced attosecond chiral sensing — •Nicola Mayer[1], Anne Weber[1], Daniele Toffoli[2,3], Margarita Khokhlova[1], and Emilio Pisanty[1] — [1]Attosecond Quantum Physics Group, King's College London, London (United Kingdom) — [2]Dipartimento di Scienze Chimiche e Farmaceutiche, Università degli studi di Trieste, Via L. Giorgieri 1, I-34127, Trieste, Italy — [3]IOM-CNR, Istituto Officina dei Materiali, 34149, Trieste, Italy

Chirality is an ubiquitous phenomenon in nature, spanning many orders of magnitude in length, from the cosmic scale in spiraling galaxies to the microscopic one in chiral molecules. The interaction of polychromatic synthetic chiral light beams (SCL) with chiral molecules is expected to enhance chiral signals in observables such as HHG or photoelectron yield. Here, we show that by using vector-vortex beams with radial and azimuthal polarization, the chirality of SCL beams carrying a chiral topological charge can be increased by two orders of magnitude, leading to a huge enhancement in chiral signals. We prove theoretically such enhancement by using an ab-initio based strong-field approximation approach to describe HHG in fenchone and camphor, with state-of-art saddle point methods to describe polychromatic three-dimensional quantum orbits in the continuum. Our results bring the goal of experimental proof of these techniques closer to reach, both in chiral molecules as well as in atoms.

A 6.5 Mon 18:15 N 1

Absolute photoemission timing in noble gases — •Maximilian Forster[1], Maximilian Pollanka[1], Sven Paul[1], Christian Schröder[1], Pascal Freisinger[1], Anatoli Kheifets[2], and Reinhard Kienberger[1] — [1]Chair for laser and x-ray physics, E11, Technische Universität München, Germany — [2]Research School of Physical Sciences, The Australian National University, Canberra ACT 0200, Australia

We measured the photoemission time delay in noble gases, namely neon and xenon across different photon energies using the attosecond streaking technique.

The photoemission delay of neon, being the first ever evidence of atomic delay, has received repeated attention by both experimental and theoretical investigations due to the large cross section and convenient properties of neon. As a helium reference is no possible for neon, we used iodoemthane as a chronoscope. The internal delay between Ne2s and Ne2p can be extracted simultaneously, allowing for a consistency check with previous experiments conducted only with neon.

The Xenon states Xe4d and Xe5s can be measured straightforward relative to helium and are compared to theoretical calculations.

A 6.6 Mon 18:30 N 1

Attosecond XUV-XUV Fourier Transform Spectroscopy of Autoionizing Rydberg States in Molecular Nitrogen — •Ignacio Martínez Casasús[1], Oleg Kornilov[2], Arnaud Rouzée[2], Luis Bañares Morcillo[1,3], and Tobias Witting[2] — [1]Departamento de Química Física, Facultad de Ciencias Químicas, Universidad Complutense de Madrid, 28040 Madrid, Spain — [2]Max Born Institute, Max-Born-Straße 2A, 12489 Berlin, Germany — [3]Instituto Madrileño de Estudios Avanzados IMDEA-Nanoscience, Faraday, 9, 28049 Madrid, Spain

We introduce attosecond XUV-XUV Fourier transform spectroscopy to investigate the autoionizing Rydberg states of molecular nitrogen. Phase-locked XUV pulse pairs are generated through high-harmonic generation and delayed with sub-10-attosecond timing precision. The first pulse prepares a coherent superposition between the molecular ground state and a set of high-lying Rydberg states. The second pulse probes the evolving coherence, imprinting delay-dependent modulations onto the population of autoionizing levels. These modulations are subsequently read out via the photoelectron spectra resulting from autoionization into different ionic continua. Fourier analysis of the delay-dependent photoelectron yields provides information about transition energies, coherence dynamics and vibrationally resolved ionization cross-sections.

A 7: Collisions, Scattering and Correlation Phenomena II (joint session A/MO)

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

A 7.1 Mon 17:00 N 2

Theory of Electronic Transitions — •Hubert Klar — retired from University Freiburg, Institut für Physik — 79000 Freiburg, Hermann-Herder-Strasse 3

Starting from the Hamilton-Jacobi frame we present a novel parabolic partial difference equation for s-wave electron atom scattering.This equation serves for initial value problems.Thanks to an unexpected separation of coordinates we calculate easily the classical action which we use later to derive a quantum wave function in the semiclassical limit including correlation. There is no way for direct excitation. That lack is filled by a correlated multielectron wave propagation along a potential ridge. The final destination of that wave is a multielectron concentration point, i. e. all correlated electrons arrive near the nucleus. In the special case of single excitation two electrons form a pair comparable to a Cooper pair.These pairs fill a lake whose elements are represented by converging and diverging Fresnel distributions. The concentration point is highly unstable, the decay leads to an excited target state plus an escaping electron.Our results are in conflict with the old Born model for several reasons. (i) We describe the electrons by matrial waves rather by mass-points. (ii) Correlation has been properly takn in account. (iii) The target electron is not kicked up but pulled up due to electron-electron attraction.

A 7.2 Mon 17:15 N 2

Asymmetries observed in vibrational dissociation of HD by proton impact — •Michael Schulz[1,2], Shruti Majumdar[1], Sujan Bastola[1], Basu Lamicchane[1], Daniel Fischer[1], Ahmad Hasan[3], and Ramaz Lomsadze[4] — [1]Missouri University of Science & Technology, Rolla, USA — [2]Max-Planck Institut für Kernphysik, Heidelberg, Germany — [3]UAE University, Al Ain, UAE — [4]Tbilisi State University, Tbilisi, Georgia

We have measured momentum-analyzed H+ and D+ molecular fragments produced in p + HD collisions in coincidence with neutralized scattering-angle resolved projectiles. From the data we extracted multiple (including fully) differential cross sections for dissociative capture. In various spectra we observed a pronounced asymmetry favoring the H+ + D0 over the H0 +D+ fragmentation channel. A qualitatively similar, but weaker asymmetry was previously found for dissociative ionization and well reproduced by theory [1]. It was explained by an isotope shift in the asymptotic molecular energy curves favoring the electron to be localized closer to the deuteron. We conclude that the same explanation holds for our results on dissociative capture. The larger magnitude of the asymmetry is probably due to the significantly smaller projectile energy.

[1] I. Ben-Itzhak et al., Phys. Rev. Lett. 85, 58 (2000)

A 7.3 Mon 17:30 N 2

Coherent Ionization of Atoms by Dense and Compact Beams of Extremely Relativistic Electrons — •Sami Kim, Carsten Müller, and Alexander B. Voitkiv — Institut für Theoretische Physik I, Heinrich-Heine-Universität Düsseldorf

Coherent ionization of atoms by very dense and compact beams of highly relativistic electrons is studied [1]. We consider and compare two coherent electron-induced ionization mechanisms, tunnel/over-barrier ionization and coherent impact ionization. In both mechanisms, a significant fraction of the beam electrons acts coherently, leading to a substantial ionization enhancement. The low-frequency components of the total beam field can coherently induce tunneling in target atoms, while the high-frequency components enable coherent impact ionization. The processes are shown to depend very sensitively on the spatiotemporal structure of these novel electron beams, which offers a means for their characterization.

[1] S. Kim, C. Müller and A. B. Voitkiv; arXiv:2508.17192v2

A 7.4 Mon 17:45 N 2

Detachment with target ionization in collisions of slow D- ions with He and Ar — •Michael Schulz[1], Felix Hermann[1], Weiyu Zhang[1], Alexander Voitkiv[2], Bennaceur Najjari[3], Maka Siddiki[1], Alexander Dorn[1], Manfred Grieser[1], Florian Grussie[1], Holger Kreckel[1], Olda Novotny[1], Andreas Wolf[1], Thomas Pfeifer[1], Claus Dieter Schröter[1], and Robert Moshammer[1] — [1]Max Planck Institut für Kernphysik, Heidelberg, Germany — [2]Heinrich Heine University, Düsseldorf, Germany — [3]Institute of Modern Physics, Chinese Academy of Sciences, Lanzhou, China

We have measured momentum-analyzed recoil-ions and ejected electrons in triple coincidence with projectiles neutralized in collisions of D- ions with He and Ar at projectile energies between 20 and 120 keV. From the data we extracted multiple-differential momentum distributions of electrons ejected in detachment accompanied by single target ionization. For the Ar target the results confirm a strong role played by a first-order correlated channel proceeding by a mutual interaction between the active projectile- and target- electrons which we observed earlier for Si- projectiles. Surprisingly, this is the case even well below the threshold energy for this mechanism pointing to the significance of the interaction between the two active electrons in this fundamental scattering process. The first-order process is important for the He target as well, however, there signatures of higher-order channels are more pronounced than for Ar. The data are qualitatively well reproduced by our higher-order calculations.

A 7.5 Mon 18:00 N 2

Rate coefficients for dielectronic recombination of the astrophysically relevant N-like Ne ion at CRYRING@ESR — •Elena-Oana Hanu[1,2,3], Michael Lestinsky[1], Carsten Brandau[1], Michael Fogle[5], Pierre-Michel Hillenbrand[1], Mirko Looshorn[6,7], Esther Menz[1,4], Stefan Schippers[6,7], Reinhold Schuch[8], Maria Tatsch[6,7], Ken Ueberholtz[9], Shu-Xing Wang[6,7], and Thomas Stoehlker[1] — [1]GSI GmbH, Darmstadt — [2]HI Jena — [3]GU Frankfurt am Main — [4]Universität zu Köln — [5]Dep. of Physics, Auburn University, USA — [6]I. Physikalisches Institut, Uni

Giessen — [7]HFHF, Giessen — [8]Dep. of Physics, Stockholm University, Sweden — [9]IKP, Uni Muenster

Dielectronic recombination of N-like Ne was studied using a merged-beams setup at CRYRING@ESR for collision energies from 0 to 25 eV. The measured energy-dependent recombination rate coefficient includes all ΔN=0 DR resonances from 2s to 2p core excitations was compared with results from theoretical calculations. The ion beam contained roughly equal fractions of ions in the ground-state and in metastable states, therefore the theoretical rates were weighted accordingly. From the measurements we derived a DR plasma rate coefficient α(T). The results agree well with previous theory for high temperatures where N-like Ne is abundant, but yield slightly higher rates at the lower temperatures typical of photoionized plasmas and collisionally ionized plasmas. Parametrized fits of the experimental DR plasma rates are provided for use in astrophysical models.

A 7.6 Mon 18:15 N 2

Electron gun optimization for electron-ion crossed-beams experiments — •B. Michel Döhring[1,2], Kurt Huber[1], Mirko Looshorn[1,2], and Stefan Schippers[1,2] — [1]Justus-Liebig-Universität Gießen — [2]Helmholtz Forschungsakademie Hessen für FAIR (HFHF), GSI Helmholtzzentrum für Schwerionenforschung GmbH, Darmstadt

Electron-impact ionization is a fundamental atomic collision process, which is of importance for a wide range of scientific and technical applications such as astrophysics, EUV lithography and fusion research [1]. Recent cross-section measurements with moderately charged xenon ions [2] and singly charged lanthanum ions [3] have demonstrated the excellent performance of our high-current electron gun, which we have designed and built in Giessen [4,5]. This gun has also served as a prototype of the transverse free electron target for CRYRING at GSI/FAIR [6]. Here, we report on our latest achievements in electron beam resolution, on measurements particularly in the low-energy region, and on future plans for optimizing the flexible electron gun.

[1] A. Müller, Adv. At. Mol. Opt. Phys. **55**, 293 (2008).
[2] F. Jin et al., Eur. Phys. J. D **78**, 68 (2024).
[3] B. M. Döhring et al., Atoms **13**, 2 (2025).
[4] W. Shi et al., Nucl. Instrum. Meth. B **205**, 201 (2003).
[5] B. Ebinger et al., Nucl. Instrum. Meth. B **408**, 317 (2017).
[6] M. Lestinsky et al., Eur. Phys. J. ST **225**, 797 (2016).

A 7.7 Mon 18:30 N 2

A Novel Compton Telescope for Polarimetry in the MeV Range: Towards Delbrück Scattering — •Tobias Over-Winter[1,2,3], Anton Kononov[1], Thomas Krings[4], Wilko Middents[1,2,3], Uwe Spillmann[1], Günter Weber[1,2], and Thomas Stöhlker[1,2,3] — [1]Helmholtz Institute Jena, Jena, Germany — [2]GSI Helmholtzzentrum für Schwerionenforschung, Darmstadt, Germany — [3]Friedrich Schiller University Jena, Jena, Germany — [4]Forschungs Zentrum Jülich, Jülich, Germany

For photon energies from several tens of keV up to a few MeV, Compton polarimetry provides insight into subtle details of fundamental radiative processes in atomic physics. Within the SPARC collaboration [1] several segmented semiconductor detectors have been developed that are well suited for application as efficient Compton polarimeters. For scattering and photon emission processes in the hard x-ray regime this kind of detector enable revealing photon polarization effects in great detail [2]. Recently, a new polarimeter has been constructed within the SPARC collaboration based on an arrangement of two segmented semiconductor crystals in a telescope structure. This design allows us to employ the Compton polarimeter in a broad energy range of photon energies from 50 keV up to 1 MeV. In my contribution I will present this detector. Additionally, I will discuss first planned experiments utilizing this detector at high photon energies up to 1 MeV.

[1] Th. Stöhlker et al. Nucl. Instrum. Methods Phys. Res. B 365 (2015) 680.
[2] K.H. Blumenhagen et al. New J. Phys. 18 (2016) 119601.

A 7.8 Mon 18:45 N 2

Single-Electron Detection at Room Temperature Using Background-Gas Ion Signals in a Penning Trap — •Arindam Kumar Sikdar[1,2], Joydip Nandi[1,2], M. Chatterjee[3], Vyshnav C.H.[4], A Ray[1], K. T. Satyajith[4], and P. Das[1,2] — [1]Variable Energy Cyclotron Centre, 1/AF Bidhannagar, Kolkata, INDIA — [2]Homi Bhabha National Institute, Anushaktinagar, Mumbai, Maharashtra, INDIA — [3]Jadavpur University, Raja Subodh Chandra Mallick Road, Jadavpur, Kolkata, INDIA — [4]Delta Q, IMJ Institute of Research, Moodlakatte, Karnataka, INDIA

We present a simple, room-temperature method for detecting a single trapped electron without relying on cryogenic electronics or image-current readout. A single electron confined in a Penning trap naturally ionizes residual background molecules, producing low-energy ions that are guided to a microchannel plate (MCP) and counted individually. These ion bursts provide a clear, indirect signature of the electron*s presence and confinement dynamics.

This ionization-based readout is highly sensitive, non-invasive, and directly compatible with hybrid trap architectures such as dual-frequency Paul traps and Penning*Paul combinations, where conventional detection is limited by weak image currents and RF noise. The technique offers a practical path toward single-lepton detection in room-temperature electron, positron, and antimatter experiments, and opens new opportunities for compact precision sensors and single-particle studies.

A 8: Precision Spectroscopy of Atoms and Ions I (joint session A/Q)

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

Invited Talk A 8.1 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.

A 8.2 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.

A 8.3 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.

A 8.4 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.

A 8.5 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.

A 8.6 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.

A 8.7 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 accceleration 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)

A 9: Ultracold Matter III – Fermions (joint session Q/A)

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

A 9.1 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 on-site 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.

A 9.2 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.

A 9.3 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)

A 9.4 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.

A 9.5 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

A 9.6 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)

A 9.7 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.

A 9.8 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)

A 10: Ultra-cold Atoms, Ions and BEC I (joint session A/Q)

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

A 10.1 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)

A 10.2 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).

A 10.3 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 $\mathcal{D}(S_3)$.

A 10.4 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)

A 10.5 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.

A 10.6 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)

A 10.7 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.

A 10.8 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.

A 11: Atomic Systems in External Fields I

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

Invited Talk A 11.1 Tue 11:00 N 2

Dichroic Electron Emission Patterns from Oriented Helium Ions — •Niclas Wieland[1], Klaus Bartschat[2], Filippa Dudda[1], Michael Meyer[3], and Markus Ilchen[1] — [1]University of Hamburg, Hamburg, Germany — [2]Drake University, Des Moines, USA — [3]European X-Ray Free-Electron Laser Facility

We report a joint experimental and theoretical study using a combination of polarization-controlled free-electron-laser (FEL) and near-infrared (NIR) pulses in a synchronized two-color photoionization scheme. Excited He+ ions, created by extreme ultraviolet (XUV) circularly polarized radiation from the XUV-FEL FERMI in the oriented 3p (m = +1) state, are exposed to circularly polarized 784-nm NIR radiation with peak intensities from 10^12 W/cm^2 to 10^13 W/cm^2. The angular distribution of the ejected electrons exhibits a strong dichroism depending on the NIR intensity. While the corotating case is defined by a single path, for the counter-rotating case, there are two dominant pathways whose relative strength and phase difference are determined.

A 11.2 Tue 11:30 N 2

Coherent control of helium photoelectron emission using ω–2ω SASE FEL pulses — •Harijyoti Mandal[1], Muwaffaq Ali Mourtada[1], Alexander Magunia[1], Weiyu Zhang[1], Yu He[1], Hannes Lindenblatt[1], Florian Trost[1], Lina Hedewig[1], Cristian Medina[1], Arikta Saha[1], Gergana D. Borisova[1], Steffen Palutke[2], Evgeny Schneidmiller[2], Mikhail Yurkov[2], Stefan Düsterer[2], Rolf Treusch[2], Chris H. Greene[3], Yimeng Wang[3], Robert Moshammer[1], Ulrike Frühling[2], Christian Ott[1], and Thomas Pfeifer[1] — [1]Max-Planck-Institut für Kernphysik, 69117 Heidelberg, Germany — [2]Deutsches Elektronen Synchrotron DESY, 22607 Hamburg, Germany — [3]Purdue University, West Lafayette, IN 47907, USA

Extreme-ultraviolet (XUV) free-electron lasers enable nonlinear ionization and interference between multiple excitation pathways, providing a platform for coherent control in the few-photon regime. We demonstrate phase-controlled ω-2ω photoionization of helium using stochastic SASE pulses at FLASH2, DESY Hamburg. Interference between one-photon (2ω) and two-photon ($\omega + \omega$) channels produces a tunable left-right asymmetry in the photoelectron angular distribution. Thin aluminium foils (100-300nm) imprint a calibrated dispersive phase shift between the fundamental ($\omega = 21.2$eV) and second harmonic ($2\omega = 42.4$eV). Fully differential momentum distributions were recorded with a reaction microscope and correlated shot-by-shot with spectral diagnostics, revealing asymmetry dependence on instantaneous photon energy, pulse intensity, and relative $\omega/2\omega$ content.

A 11.3 Tue 11:45 N 2

Modeling dissipation in quantum active matter — Alexander P. Antonov[1], Sangyun Lee[2], Benno Liebchen[3], Hartmut Löwen[1], Jannis Melles[1], Giovanna Morigi[4], Yehor Tuchkov[2], and •Michael te Vrugt[2] — [1]Institut für Theoretische Physik II, Weiche Materie, Heinrich-Heine-Universität Düsseldorf — [2]Institut für Physik, Johannes Gutenberg-Universität Mainz — [3]Institut für Physik der kondensierten Materie, Technische Universität Darmstadt — [4]Theoretische Physik, Universität des Saarlandes

Active particles, such as flying birds and swimming bacteria, are a widely studied class of systems in classical soft matter physics. Recently, there have been a variety of suggestions for how to realize activity on a quantum level in cold atom systems. Here, we investigate one particular way in which such quantum active matter may differ from its classical counterpart, namely the way in which it is influenced by dissipation. We find that the choice of the quantum heat bath strongly influences the dynamics of quantum active matter at short timescales, which is the regime in which quantum effects are most relevant.

A 11.4 Tue 12:00 N 2

Trapped Rydberg ions as quantum simulators for coupled exciton-phonon dynamics — •Simon Euchner[1], Mathias B. M. Svendsen[1], and Igor Lesanovsky[1,2] — [1]Universität Tübingen, Auf der Morgenstelle 14, 72076 Tübingen, Germany — [2]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

Trapped Rydberg ions combine electronic and motional degrees of freedom, which can be coupled in a controllable fashion. This opens opportunities for the quantum simulation of molecular processes native to light-harvesting complexes, such as excitation energy (exciton) transport influenced by exciton-phonon (vibronic) coupling. We investigate how such a simulator could be designed, thereby highlighting its feasibility with state-of-the-art technology. Subsequently, we focus on a simplified model for the simulator. Based on this model we study finite temperature effects and the impact of different motional initial states on the dynamics. Moreover, we find that for certain motional states, two-phonon processes become relevant which can facilitate the exciton transport.

A 11.5 Tue 12:15 N 2

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.

A 11.6 Tue 12:30 N 2

On classically mediated quantum entanglement — •Sebastian Ulbricht[1,2], Andrés Darío Bermúdez Manjarres[3], and Marcel Reginatto[2] — [1]Institut für Mathematische Physik, Technische Universität Braunschweig, Mendelssohnstraße 3, 38106 Braunschweig, Germany — [2]Physikalisch-Technische Bundesanstalt PTB, Bundesallee 100, 38116 Braunschweig, Germany — [3]Universidad Distrital Francisco José de Caldas, Cra. 7 No. 40B-53, Bogotá, Colombia

The question of whether quantum states can become entangled when they interact via a classical mediator is still a matter of ongoing discussion. This lively debate is deeply interwoven with the question of whether entanglement studies can prove the quantum - or classical - nature of gravity. In recent years, there have been numerous statements and no-go theorems, supporting one or the other position. However, while appearing to be universal, no-go theorems 'forbidding' classically mediated quantum entanglement do depend on the used quantum-classical hybrid theory. In this talk, we show that in Hybrid van Hove theory [1] two initially uncorrelated spins can become entangled even if they are only coupled via a classical harmonic oscillator. We further demonstrate that the spin-spin correlations and the entanglement of the spins closely resemble the fully quantum case. Our investigation shows that existing no-go theorems are not universal. It further implies that consistent quantum theories featuring classical gravity cannot be categorically ruled out by quantum entanglement studies. [1] M. Reginatto, A.D. Bermúdez Manjarres, and S. Ulbricht, J. Phys.: Conf. Ser. 3017 012037 (2025)

A 11.7 Tue 12:45 N 2

Estimating quantum entropies using a quantum circuit and a neural network — •Sangyun Lee[1], Hyukjoon Kwon[2], and Jae Sung Lee[3] — [1]Institut für Physik, johannes gutenberg university — [2]School of Computational Sciences, Korea Institute for Advanced Study, Seoul 02455, Korea — [3]School of Physics, Korea Institute for Advanced Study, Seoul, 02455, Korea

Entropy is one of the key quantities in physics. In particular, it plays important roles in phase transitions, heat engines, information processing, and entanglement. However, estimating entropy is difficult because it is not a standard physical observable and requires access to the full probability distribution of the system. To address this challenge, we propose a method that combines a quantum circuit with a neural network. Our approach is applicable to von Neumann entropy and Rényi entropy. We validate our method on an XXZ chain model and find that it can sensitively estimate the model*s entanglement entropy.

A 12: Precision Spectroscopy of Atoms and Ions II (joint session A/Q)

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

Invited Talk A 12.1 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).

A 12.2 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.

A 12.3 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.

A 12.4 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.

A 12.5 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.

A 12.6 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.

A 12.7 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)

A 13: Highly Charged Ions and their Applications II

Time: Tuesday 11:00–12:45 Location: N 25

Invited Talk A 13.1 Tue 11:00 N 25

Identifications of clock transitions in heavy highly charged ions with high sensitivity to physics beyond the Standard Model — Nils-Holger Rehbehn[1], Lakshmi P. Kozhiparambil Sajith[1,2], Michael K. Rosner[1], Charles Cheung[3], Sergey G. Porsev[3], Marianna S. Safronova[3], Samuel M. Brewer[8], Steven Worm[2], Dmitry Budker[4,5,6,7], Thomas Pfeifer[1], José R. Crespo López-Urrutia[1], and •Hendrik Bekker[4,5,6] — [1]Max-Planck-Institut für Kernphysik, 69117 Heidelberg, Germany — [2]DESY, D15738 Zeuthen, Germany — [3]Department of Physics and Astronomy, University of Delaware, Newark, Delaware 19716, USA — [4]Johannes Gutenberg-Universität Mainz, 55122 Mainz, Germany — [5]Helmholtz Institute Mainz, 55099 Mainz, Germany — [6]GSI Helmholtzzentrum für Schwerionenforschung GmbH, 64291 Darmstadt, Germany — [7]Department of Physics, University of California, Berkeley, CA 94720-7300, USA — [8]Department of Physics, Colorado State University, Fort Collins, Colorado 80523, USA

Atomic theory predicts numerous optical transitions in a plethora of highly charged ions with exquisite sensitivity to new physics. However, large ucertainties arise due to the complexity of the atomic structures, precluding direct application of state-of-the-art frequency metrology techniques. We present measurements of $Os^{15,16,17+}$ and Pr^{10+} at an electron beam ion trap leading to atomic-theory-supported identifications of transitions suitable for new-physics searches. The discovered electric quadrupole (E2) transitions of Os^{16+} are especially suitable for frequency metrology due to their small linewidth down to 44 μHz.

A 13.2 Tue 11:30 N 25

Laser cooling of bunched relativistic ion beams at the FAIR SIS100 — •Danyal Winters[1], Michael Bussmann[2,3], Tamina Grunwitz[4], Jens Gumm[4], Volker Hannen[5], Thomas Kühl[1,6], Sebastian Klammes[1], Benedikt Langfeld[4], Ulrich Schramm[2,7], Denise Schwarz[4], Mathias Siebold[2], Peter Spiller[1], Thomas Stöhlker[1,6,8], Ken Ueberholz[5], and Thomas Walther[4,9] — [1]GSI Darmstadt — [2]HZDR Dresden — [3]CASUS Görlitz — [4]TU-Darmstadt — [5]Uni Münster — [6]HI-Jena — [7]TU-Dresden — [8]Uni-Jena — [9]HFHF Campus Darmstadt

The heavy-ion synchrotron SIS100 is (at) the heart of the Facility for Antiproton and Ion Research (FAIR) in Darmstadt, Germany. It is designed to accelerate intense beams of heavy highly charged ions up to relativistic velocities and to deliver them to unique physics experiments, such as those planned by the APPA/SPARC collaboration. In order to cool these extreme ion beams, bunched beam laser cooling will be applied using a dedicated facility at the SIS100. We will use a novel 3-beam concept, where laser beams from three complementary laser systems (cw and pulsed) will be overlapped in space, time and energy to interact simultaneously with a very broad ion velocity range in order to maximize the cooling efficiency. We will present this project and give an update of its current status. We will also give an overview of the laser and detector systems that will be used.

A 13.3 Tue 11:45 N 25

Stringent Constraints on New Pseudoscalar & Vector Bosons from Precision Hyperfine Splitting Measurements — •Cedric Quint[1], Fabian Heisse[1], Joerg Jaeckel[2], Lutz Leimenstoll[2], Christoph H. Keitel[1], and Zoltán Harman[1] — [1]Max Planck Institute for Nuclear Physics, Saupfercheckweg 1, 69117 Heidelberg — [2]Insitute for Theoretical Physics, Philosophenweg 16, 69120 Heidelberg

Axion-like particles and similar new pseudoscalar as well as vector bosons coupled to nucleons and electrons are predicted to lead to spin-dependent forces in atoms and ions. We argue that hyperfine structure measurements in hydrogen- and lithium-like charge states are a sensitive probe to this effect. Employing specific differences of these splittings reduces uncertainties due to nuclear effects in hyperfine structure calculations and measurements. Using this, we show that existing measurements on Be provide competitive limits in the region $m_\phi \gtrsim 100$ keV, improving upon existing constraints by up to a factor of 2 for pseudoscalar couplings. We also find that future measurements on

Cs have a further factor of 2 – 2.5 improved discovery potential for pseudoscalars and an order of magnitude for new vector bosons when compared with the corresponding current constraints.
Reference: 2506.03274

A 13.4 Tue 12:00 N 25

Atomic parity violation in highly charged ^{40,48}Ca and ^{208}Pb ions — •Anna Viatkina[1,2], Christopher Mertens[3], Ben Ohayon[4], Vladimir Yerokhin[5], and Andrey Surzhykov[1,2] — [1]Technische Universität Braunschweig, 38106 Braunschweig, Germany — [2]Physikalisch-Technische Bundesanstalt, 38116 Braunschweig, Germany — [3]Rheinisch-Westfälische Technische Hochschule Aachen, 52062 Aachen, Germany — [4]Technion-Israel Institute of Technology, Haifa 3200003, Israel — [5]Max-Planck-Institut für Kernphysik, 69117 Heidelberg, Germany

We calculate parity-violation-induced E1 amplitudes for the $1s \to 2s$ and $1s^22s \to 1s^23s$ transitions in H- and Li-like ions of ^{40}Ca, ^{48}Ca, and ^{208}Pb; neutron skin effects and nuclear uncertainties are included for each nucleus. We consider spin-independent weak-interaction contribution of the Z^0 boson described by standard model, as well as the effects of a hypothetical new Z' boson of varying mass. We conclude that the neutron-skin corrections in the ^{40,48}Ca isotope pair can be mostly neglected when considering Z' boson effects, which is an advantage for the search for new parity-violating physics. On the other hand, both the neutron skin effect and the sensitivity to hypothetical Z' interactions in ^{208}Pb is shown to be significant.

A 13.5 Tue 12:15 N 25

Particle Motion Inside the HITRAP Penning Trap — •Jonas Ködel for the HITRAP-Collaboration — Institut für Kernphysik, TU Darmstadt, Schloßgartenstr. 9, Darmstadt, Germany — Helmholtz Graduate School for Hadron and Ion Research, Germany

The HITRAP (**hi**ghly charged ion **trap**) facility located at the GSI Helmholtzzentrum für Schwer-ionenforschung in Darmstadt provides the unique ability to decelerate heavy, accelerator-produced highly charged ions (HCI) down to 6keV/nucleon and cool to eV equivalent temperature. To facilitate electron cooling of a single charge state inside HITRAP's Penning trap, the motion of HCI inside a cylindrical Penning trap is explored.

We present our findings on the modes of motion of highly charged Argon ions inside the HITRAP Penning trap. By leveraging intentional over-excitation of stored ions by radio frequency, the characteristic frequencies of axial-, magnetron- and reduced cyclotron motion are extracted. With the full length of the cylindrical trap used for ion capture, the electrode potential is flat, rather than hyperbolic, hence the typical eigenmotion frequencies are mixed. Lastly, the effects of changes in the Penning trap's magnetic field, the ion's charge state, and the Penning trap's potential on the three characteristic frequencies are shown.

A 13.6 Tue 12:30 N 25

The Microwave Cavity Penning Trap for the Lsym Experiment — •Paul Holzenkamp, Maria Pasinetti, Fabian Raab, Leonie Marzel, Sarah Placek, Andreas Thoma, Sangeetha Sasidharan, and Sven Sturm — MPIK, Heidelberg, Germany

Lsym is a cryogenic Penning trap experiment, aiming to significantly improve the precision of CPT tests for the electron and positron. Specifically, we will look for an asymmetry in their charge-to-mass ratio as well as their g-factors or determine stringent limits. The trap will be cooled to about 300 mK to minimize transition rates out of the ground states of the cyclotron and axial motion, respectively. While the cyclotron motion cools via synchrotron radiation, for the axial motion, cavity assisted side-band cooling will be employed. To this end, the main Penning trap ("CavityTrap") not only should provide a highly harmonic trapping potential but also needs to support efficient millimeter wave spin control drives at the Larmor frequency and axial sideband, while efficiently rejecting photons at the cyclotron frequency. To achieve this, both the mode structure and the in-coupling of the microwaves into the cavity have to be designed appropriately. Additionally, the CavityTrap should allow for the separation of the singly charged helium ion and the positron that are trapped together. Numerical simulations are used to design the CavityTrap geometry in order to simultaneously fulfill the requirements for the microwave cavity structure and also optimize the electrostatic potential of the Penning trap. I will show the current status of the Lsym CavityTrap design.

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

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

A 14.1 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 systematics 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).

A 14.2 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.

A 14.3 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.

A 14.4 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.

A 14.5 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).

A 14.6 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.

A 14.7 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.

A 14.8 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).

A 14.9 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.

A 14.10 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.

A 14.11 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.

A 14.12 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).

A 14.13 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.

A 14.14 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.

A 14.15 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)

A 14.16 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.

A 14.17 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.

A 14.18 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.

A 14.19 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)

A 14.20 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.

A 14.21 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 $\approx 40\,kg$ 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)

A 14.22 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.

A 14.23 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)

A 14.24 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.

A 14.25 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.

A 14.26 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 $^2S_{1/2} \rightarrow {}^2D_{3/2}$ 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.

A 14.27 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 $^2S_{1/2} \rightarrow {}^2F_{7/2}$ 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 $^2S_{1/2} \rightarrow {}^2D_{3/2}$ 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.

A 14.28 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)

A 14.29 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.

A 15: Poster – Highly Charged Ions and their Applications

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

A 15.1 Tue 17:00 Philo 1. OG

Efficient production of ^{229m}Th via Cascade Decay — •Yumiao Wang[1,2] and Changbo Fu[1] — [1]Fudan University, Shanghai, China — [2]Johannes Gutenberg Universität Mainz, Germany

The low-energy nuclear isomeric state of ^{229m}Th (8.36 eV) provides a unique bridge between nuclear and atomic physics, with promising applications in nuclear clocks and precision metrology. However, its efficient and controllable population remains a long-standing experimental challenge.

An indirect excitation scheme based on nuclear cascade decay in an electron beam ion trap (EBIT) and a storage ring (SR) is formulated for highly charged ^{229}Th ions, for which the strengthened electron–nucleus interaction leads to enhanced excitation cross sections. In this scheme, ^{229}Th nuclei are first excited to higher-lying nuclear states via electron-induced processes, namely nuclear excitation by inelastic electron scattering (NEIES) and nuclear excitation by electron capture (NEEC). The corresponding excitation cross sections are calculated within the Dirac-Hartree-Fock-Slater framework.

This study establishes a unified theoretical scheme linking electron-induced nuclear excitation and cascade nuclear relaxation in EBIT and SR environments, providing a realistic pathway toward the efficient and controllable production of ^{229m}Th.

This work is supported by the National Natural Science Foundation of China (NSFC) under Grant No. 12235003 and the China Scholarship Council (CSC).

A 15.2 Tue 17:00 Philo 1. OG

Optimised Y-bender design for efficient ion transport — •Sophia Dorra, Stepan Kokh, Magdalena Winkelvoss, Anton Sterr, Melina Gizewski, Finja Mayer, Maili Schube, José Ramon Crespo López-Urrutia, Thomas Pfeifer, and Vera Schäfer — Max-Planck-Institut für Kernphysik, Heidelberg, Germany

Precision spectroscopy to search for possible variations of the fine-structure constant α require atomic systems with strong relativistic level shifts. Highly charged ions (HCIs) are ideal candidates, but experiments involving rare isotopes such as californium demand efficient production, transport, and retrapping of HCIs. In our setup, HCIs are generated in an electron beam ion trap (EBIT) and subsequently transferred to one of two Paul traps for high-precision spectroscopy of selected transition frequencies.

To maximize the overall transmission efficiency from the EBIT to the trapping region, we are developing a new Y-bender beamline element composed of two symmetric 45° electrostatic benders. This design enables deflection of the HCI beam to either side while preserving beam quality and improving transport efficiency compared to a single 90° deflection. As a preparatory step toward constructing the Y-bender, we investigate the geometric and electrostatic properties of a previously used 90° bender. The goal of these measurements and simulations is to understand how electrode geometry influences beam focusing and transmission in order to optimize the design of our 45° bender modules.

A 15.3 Tue 17:00 Philo 1. OG

Hyperfine-induced transitions of nuclei and atoms — •Stephan Fritzsche[1,2], Houke Huang[1], Wu Wang[3], and Yong Li[3] — [1]Helmholtz-Institut Jena, Germany — [2]Friedrich-Schiller University Jena, Germany — [3]Hainan University, Haikou 570228, China

The hyperfine interaction between nuclear moments and the electronic charge and current distributions is present in all atoms and ions with non-zero nuclear spin I. However, this interaction becomes visible only in transition probabilities, lifetimes and angular distribution of emitted photons, if the combined system "nucleus + electrons" supports additional multipole transitions, which are not accessible alone for the individual subsystems. Different communities have studied such "hyperfine phenomena" with varying notations and physical pictures in mind, including hyperfine transitions, the nuclear hyperfine effect or various kinds of (so-called) electron-bridge processes [1,2]. We here show how all these phenomena can readily be interpreted as special cases of hyperfine-induced nuclear and/or electronic multipole transitions.

[1] W. Wang, F. Zou, S. Fritzsche and Y. Li; Isomeric population transfer of the 229 Th nucleus via hyperfine electronic bridge; Phys. Rev. Lett. 133, 223001 (2024). [2] W. Wang, S. Fritzsche and Y. Li; Search for variations of the fine-structure constant via the hyperfine electronic bridge in highly charged 229Th ions; Phys. Rev. A112, 022811 (2025).

A 15.4 Tue 17:00 Philo 1. OG

Interplay of Hyperfine Mixing and Nuclear-Atomic Interactions in Highly Charged Ions — •Kaiqiang Shi[1,2,3], Xinwen Ma[1,2], and Adriana Pálffy[3] — [1]Institute of Modern Physics, Chinese Academy of Sciences, Lanzhou, China — [2]School of Nuclear Science and Technology, University of Chinese Academy of Sciences, Beijing, China — [3]Institute of Theoretical Physics and Astrophysics, University of Würzburg, Würzburg, Germany

As nuclear-scale effects become increasingly relevant in atomic physics, it is crucial to understand how atomic and nuclear degrees of freedom couple in ions. Nuclear hyperfine mixing (NHM) [1] is central to this problem. Beyond its role in ^{229}Th, recent theory [2] suggests that boronlike ^{205}Pb ions, with a 2.329 keV nuclear transition, may show strongly enhanced NHM-driven decay, greatly shortening the isomer's radiative lifetime. This indicates that systems other than ^{229}Th could also serve as platforms for studying nuclear-atomic coupling.

Bound internal conversion (BIC), the inverse of NEET [3], offers another channel linking nuclear excitation to the electronic shell. Although NHM and BIC are subject to different requirements—magnetic coupling versus energy matching—some heavy nuclei with low-lying transitions may naturally meet both. We investigate such cases, in which the interplay between NHM and BIC becomes significant and must be considered when analyzing nuclear decay in complex ionic environments.

[1] V. M. Shabaev et al., Phys. Rev. Lett. 128, 043001 (2022).
[2] W. Wang and X. Wang, Phys. Rev. Lett. 133, 032501 (2024).
[3] S. K. Arigapudi and A. Pálffy, Phys. Rev. A 85, 012710 (2012).

A 15.5 Tue 17:00 Philo 1. OG

Convolutional Neural Network for fast and accurate ion-number counting with Micro-Channel Plate detector — •Jun Huang[1], Stefan Ringleb[1], Manuel Vogel[2], and Thomas Stöhlker[1,2,3] — [1]Friedrich-Schiller-Universität Jena — [2]GSI Helmholtzzentrum für Schwerionenforschung Darmstadt — [3]Helmholtz-Institut Jena

Micro-channel plates (MCP) are ideal detectors for detecting and counting ions extracted from ion traps as long as the ion rate is low enough to detect single ion hits. During our laser experiment with the HILITE Penning trap, a huge amount of ions are expected to arrive at the MCP within microseconds, hence overlapping of multiple ions is very probable. The manual data evaluation is time consuming, as a large amount of datasets is expected. A Convolutional Neural Network (CNN) is extremely helpful in handling two-ion signals overlapping in order to recognise and count them rapidly in large datasets. In our evaluation method, single-ion signals are first hand selected and trained into a CNN of Single Ion Model (SIM) for detection with high accuracy. Due to the low number of existing double-ion data for model training, the single-ion data is used to create artificial double-ion signal, which enrich the training data for CNN of Double Ion Model

(DIM). In our created CNN models, single-ion signals and double-ion signals are rapidly recognised by SIM and DIM, and the detection is then used to obtain the total ion number. We will present the model and its ion counting capabilities with a special focus on detection accuracy.

A 15.6 Tue 17:00 Philo 1. OG

Laser spectroscopy of highly charged ions in SpecTrap — •Rima X. Schüssler[1,2,3], Manuel Vogel[1], Volker Hannen[4], Wilfried Nörtershäuser[5], Gerhard Birkl[5], Andreas Solders[6], and Thomas Stöhlker[1,2,3] — [1]GSI Helmholtzzentrum für Schwerionenforschung GmbH, Darmstadt — [2]Helmholtz Institute Jena — [3]Friedrich Schiller Universität Jena — [4]Universität Münster — [5]Universität Darmstadt — [6]Uppsala Universitet

Heavy, highly charged ions (HCI) provide a unique possibility to test fundamental physics in the presence of extreme electromagnetic fields. To this end, the SpecTrap experiment, located at the HITRAP facility of the GSI Helmholtz Centre for Heavy Ion Research, plans to perform laser spectroscopy of (hyper-)fine structure transitions in HCIs in a Penning trap. Measurements will include the test of bound-state quantum electrodynamics as well as the nuclear clock transition in $^{229}Th^{89+}$ in the framework of the HiThor project.

The HCIs are produced in the accelerators of GSI and then decelerated by the HITRAP facility, before being guided to the cryogenic Penning trap. Within the trap, they are sympathetically cooled down with Mg^{+} ions. The trap has optical access for lasers as well as to collect fluorescence of the HCIs.

A 15.7 Tue 17:00 Philo 1. OG

Lamb shift and g-factor shift calculations due to vacuum polarization in s states — •Jay Dipakbhai Solanki, Zoltán Harman, and Christoph H. Keitel — Max-Planck-Institut für Kernphysik, Heidelberg, Germany

Two-loop vacuum polarization contributions to the Lamb shift and the bound-electron g factor are calculated with perturbative quantum electrodynamics (QED) and some concepts from relativistic quantum mechanics. The g factor – or magnetic moment – of an electron bound in the strong Coulomb potential of a nucleus can nowadays be measured to an astonishing accuracy [1], enabling QED tests at the two-loop level. The Källén-Sabry potential describing certain diagrams is rederived using the optical theorem. The corresponding g factor shifts are calculated analytically from the expectation value of the potential using some simple properties of the Dirac equation. The results reproduce and extend corrections derived in the framework of nonrelativistic QED. — [1] J. Morgner, B. Tu, C. M. König, *et al.,* Nature **622**, 53 (2023).

A 15.8 Tue 17:00 Philo 1. OG

Highly charged ion beamline for efficient ion transmission with charge state selection — •Shreya Rao Kodancha, Sebastian Davidson, Elwin A. Dijck, Ruben B. Henninger, Devanarayanan Rajeeb Kumar, Vera M. Schäfer, Thomas Pfeifer, and José R. Crespo López-Urrutia — Max Planck Institute for Nuclear Physics

Highly charged ions (HCIs) are promising candidates for searches for physics beyond the Standard Model, such as King plot isotope shift studies. In the VAUQSI apparatus under development, HCIs will be interrogated in a cryogenic superconducting RF Paul trap, where the anticipated low Lamb*Dicke factor should enable efficient ground-state cooling. HCIs produced in the electron beam ion trap (EBIT) must be transported to the trap through a low-energy beamline consisting of multiple electrostatic lenses for focusing, a 90° bender for steering, and a pulsed drift tube for deceleration and bunching. Charge-state and isotope selection along the beam path will also be explored. Optimizing ion transmission involves a large parameter space, including electrode voltages, EBIT extraction rate and switching times for charge-selection electrodes. Building on our experience with the CryPTEx-SC beamline, automated optimization tools will be employed. We report on the beamline design, accompanying simulations, current progress and the planned optimization for VAUQSI.

A 15.9 Tue 17:00 Philo 1. OG

Development of a rare-isotope injector for optical spectroscopy of highly charged ions at HD-EBIT — •Nutan Kumari Sah[2], Lakshmi Priya Kozhiparambil Sajith[2], Filipe Grillo[2], Joschka Goes[1], Thomas Pfeifer[1], Steven Worm[2], Hendrik Bekker[3], and José R. Crespo López-Urrutia[1] — [1]Max-Planck-Institut für Kernphysik, D-69117 Heidelberg, Germany — [2]DESY, D-15738 Zeuthen, Germany — [3]Helmholtz Institute Mainz, 55099 Mainz, Germany

Highly charged ions (HCI) are promising candidates for advanced frequency metrology and precision tests of fundamental physics. Transitions between their strongly bound electronic states are insensitive to external perturbations. Interestingly, the presence of a $5f - 6p$ orbital crossing in several charge states of californium enables strongly forbidden optical transitions with exceptionally high sensitivity to a hypothetical variation of the fine-structure constant. However, due to theoretical uncertainties emission spectroscopy is needed to accurately determine their wavelengths for future frequency metrology. We are implementing at the superconducting Heidelberg electron beam ion trap a laser-ablation-based injection system requiring only nanogram amounts of californium and other rare elements. We will present an update and outline the next steps towards spectroscopy of californium HCI.

A 16: Ultracold Matter IV – Bosons, Rydberg Systems, and Others (joint session Q/A)

Time: Wednesday 14:30–16:30 Location: P 2

A 16.1 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.

A 16.2 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).

A 16.3 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.

A 16.4 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.

A 16.5 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).

A 16.6 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.

A 16.7 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)

A 16.8 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.

A 17: Ultra-cold Atoms, Ions and BEC II (joint session A/Q)

Time: Wednesday 14:30–16:30 Location: N 1

Invited Talk A 17.1 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.

A 17.2 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.

A 17.3 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.

A 17.4 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)

A 17.5 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.

A 17.6 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.

A 17.7 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.

A 18: Interaction with Strong or Short Laser Pulses I (joint session A/MO)

Time: Wednesday 14:30–16:15 Location: N 2

Invited Talk A 18.1 Wed 14:30 N 2

Cross-process interference in single-cycle electron emission from metal needle tips — •Anne Herzig[1], Peter Hommelhoff[2], Eleftherios Goulielmakis[1], Thomas Fennel[1], and Lennart Seiffert[1] — [1]Institute of Physics, University of Rostock, 18059 Rostock, Germany — [2]Faculty of Physics, Ludwig Maximilian University Munich, 80799 Munich, and Department of Physics, Friedrich Alexander University Erlangen-Nuremberg, 91058 Erlangen, Germany

Photoelectron spectra from strong-field ionization exhibit energy cutoffs and interference patterns from direct and backscattered electrons. While cutoffs at 2 U_p and 10 U_p follow from the three-step model, observed fringe structures are usually linked to interference within either emission channel. However, cross-process interference (CPI) *between* direct and backscattered electrons remains largely unexplored. With single-cycle pulses limiting emission to one optical cycle [1] and nanotips directing electrons into a single half-space [2], conditions arise under which CPI can be clearly resolved.

In our recent study [3], we predict carrier-envelope-phase-dependent spectra with clear CPI signatures by comparing TDSE simulations with a trajectory model extended by quantum interference. The resulting fringe pattern encodes sub-cycle information on the near-field acceleration dynamics, highlighting CPI as a promising route toward ultrafast solid-state photoemission metrology.

[1] M.T. Hassan et al., Nature 530, 66-70 (2016)
[2] S. Zherebtsov et al., Nature Physics 7, 656-662 (2011)
[3] A. Herzig et al., https://arxiv.org/abs/2509.01524 (2025)

A 18.2 Wed 15:00 N 2

Multiphoton ionization with three-dimensional laser fields — •Hans-Christian Ahlswede, Darius Köhnke, Tim Bayer, and Matthias Wollenhaupt — Carl von Ossietzky Universität Oldenburg

We report the first observation of free-electron angular momentum wave packets generated by atomic multiphoton ionization with bichromatic three-dimensional (3D) polarization-tailored ultrashort laser fields. These fields, created by the non-collinear superposition of two polarization-shaped pulses of different colors from a supercontinuum polarization pulse shaper, provide electric-field components along all spatial directions. The resulting photoelectron momentum distributions, recorded via velocity map imaging, demonstrate full 3D coherent control of electronic superposition states extending beyond the constraints of planar polarization fields by unlocking all dipole selection rules $\Delta m = 0, \pm 1$. As an application, 3D pump*probe fields are used to image previously unobserved photoelectron wave packets mapping spin-orbit dynamics of the potassium $3d$ fine structure doublet. Our shaper-based approach establishes a route to fully controllable 3D light fields for chiral-sensitive light-matter interactions and ultrafast spectroscopy.

A 18.3 Wed 15:15 N 2

Towards a velocity-map-imaging spectrometer for ultracold atoms — •Lasse Paulsen[1], Julian Fiedler[1], Jette Heyer[1], Markus Drescher[1], Klaus Sengstock[1], Klaus Bartschat[2], Juliette Simonet[1], and Philipp Wessels-Staarmann[1] — [1]Center for Optical Quantum Technologies, Universität Hamburg, Hamburg, Germany — [2]Department of Physics and Astronomy, Drake University, Des Moines, USA

The intense electric field of femtosecond laser pulses enables the ultrafast creation of ions and electrons within an ultracold quantum gas. This opens new possibilities for investigating the dynamics of ionic impurities and atom-ion hybrid systems, provided that the kinematics of the ionization process are well understood.

Here we report on the characterization of an electron velocity-map-imaging spectrometer for ultracold quantum gases, as part of a novel coincidence detection unit including an ion microscope. For characterization a pulsed krypton gas jet is ionized by femtosecond laser pulses with a center wavelength of 511 nm and peak intensities around 6×10^{13} W/cm^2. The measured photoelectron momentum distribution is compared to theoretical predictions based on the solution of the time-dependent Schrödinger equation, which confirm the observed significant shifts in the photoelectron energies caused by the high peak intensities.

This work is funded by the Cluster of Excellence "CUI: Advanced Imaging of Matter" of the DFG - EXC 2056 - project ID 390715994 and by the NSF under project Nos. PHY-2110023 and PHY-2408484.

A 18.4 Wed 15:30 N 2

Modeling ultrafast plasma formation in dielectrics — •Julia Apportin[1], Christian Peltz[1], Thomas Fennel[1], Misha Ivanov[2], and Anton Husako[2] — [1]Institute for Physics, Rostock, Germany — [2]Max Born Institute, Berlin, Germany

Laser induced damage in dielectrics due to short pulse excitation plays a major role in a variety of scientific and industrial applications, such as the preparation of 3D structured evanescently coupled wave-guides [1] or nano-gratings [2]. The corresponding irreversible material modifications predominantly originate from higher order nonlinearities like strong field ionization and plasma formation, which makes their consistent description imperative for any kind of theoretical modeling. In particular the associated feedback effects on the field propagation can have drastic implications.

We developed a numerical model, that combines a local description of the plasma dynamics in terms of corresponding rate equations for ionization, collisions and heating [3] with a fully electromagnetic field propagation via the Finite-Difference-Time-Domain method, adding self-consistent feedback effects like the sudden buildup of plasma mirrors. Considering laser pulses of constant energy (30 nJ), we investigate the influence of pulse duration and focus size on material modification and compare the resulting geometries, energy deposition and critical plasma volume.

[1] L. Englert et al, Opt. Express 15, 17855-17862 (2007)
[2] M. Alameer et al, Opt. Lett. 43, 5757-5760 (2018)
[3] B. Rethfeld, Phys. Rev. B 73 035101 (2006)

A 18.5 Wed 15:45 N 2

Photoinduced transient symmetry breaking and non-linear anomalous Hall responses in centrosymmetric 2D materials — •Arkajyoti Maity, Ulf Saalmann, and Jan-Michael Rost — Max Planck Institute for the Physics of Complex Systems, Dresden

We theoretically investigate the prospect of inducing a non-trivial, non-linear Hall response in Dirac materials obeying both inversion and time-reversal symmetries, specifically pristine graphene. This is possible by creating a non-thermal electronic distribution in the system by driving it with a finite duration ultrafast sub-cycle laser pulse. The resultant non-equilibrium state, generated by non-adiabatic transitions induced by the laser, can be made to break the general trigonal (C3) symmetry of the Hamiltonian and hence allow for a second-order Hall response to a weak electric probe, closely related to the quantum geometry of the system

A 18.6 Wed 16:00 N 2

High-harmonic generation in an organic molecular crystal — •Falk-Erik Wiechmann[1,2], Samuel Schöpa[1], Lina Marie Bielke[1], Svenja Rindelhardt[1], Serguei Patchkovskii[3], Felipe Morales[3], Maria Richter[3], Dieter Bauer[1,2], and Franziska Fennel[1,2] — [1]Intitute of physics, University of Rostock, 18059 Rostock, Germany — [2]Department of Life, Light and Matter, University of Rostock, 18059 Rostock — [3]Max Born Institute (MBI) for Nonlinear Optics and Short Pulse Spectroscopy, 12489 Berlin, Germany

Recently, organic molecular crystals (OMCs) were introduced as a novel target class for high-harmonic generation (HHG)[1], bridging the gap between gas-phase and solid-state targets. In OMCs, neighboring molecules experience a weak van-der-Waals coupling, which leads to solid like features, e.g. a delocalization of the electronic states over several unit cells. The perfect inherent alignment of all molecules makes OMCs an ideal target class for high-harmonic spectroscopy of large organic molecules, as it avoids the need for extremely challenging alignment techniques that have so far prevented corresponding measurements in the gas phase. With a fundamental 4000 nm mid-IR beam reaching 0.99 TW/cm2 we demonstrate that HHG from Pentacene crystals is possible without imposing physical damage. Measurements of the harmonic yield as a function of the driving polarization direction reveal that the harmonic generation process is driven by intermolecular effects and not by the response of non-interacting aligned molecules.
[1] Wiechmann, FE. et al., Nat. Commun. 16, 9890 (2025)

A 19: Precision Spectroscopy of Atoms and Ions III (joint session A/Q)

Time: Wednesday 14:30–16:30 Location: N 3

Invited Talk A 19.1 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).

A 19.2 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).

A 19.3 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.

A 19.4 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.

A 19.5 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.

A 19.6 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.

A 19.7 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).

A 20: Poster – Atomic Clusters

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

A 20.1 Wed 17:00 Philo 1. OG

Towards experimental studies of interatomic Coulombic electron capture (ICEC) — •Andre Giraldi[1], Deepthy Mootheril[1], Nicolas Sisourat[2], Thomas Pfeifer[1], and Alexander Dorn[1] — [1]Max Planck Institut für Kernphysik, Heidelberg, Germany — [2]Sorbonne Universite, Paris, France

This work targets the experimental detection of an environment assisted atomic decay mechanism, referred to as Interatomic Coulombic Electron Capture, or ICEC. This process consists of a free electron being captured by an atom or molecule, and the excess energy being transferred to a neighbor, ionizing or exciting it. Despite the promising theoretical results [1], there has been so far no experimental detection of ICEC. Aiming to obtain first experimental results, we propose a reaction envolving NeAr dimers:

e + Ne(2p6)Ar –> Ne*-(2p5 3s2)Ar –> Ne-(2p5 3s)Ar+ + e –> NeAr + e + hf

Presently we are adapting an electron and ion momentum spectrometer (reaction microscope) and are optimizing the formation of mixed neon-argon dimers or larger clusters. First results on electron impact ionization will be presented, which confirm the formation of the mixed species and show reactions like Interatomic Coulombic Decay (ICD) taking place.

[1] Jan Šenk, Vincent Graves, Jimena D. Gorfinkiel, Přemysl Kolorenč, Nicolas Sisourat. J. Chem. Phys. 7 November 2024; 161 (17): 174113.

A 20.2 Wed 17:00 Philo 1. OG

Experimental investigation of non-nearest-neighbour ICD after 2s ionization in Ne clusters — •Johannes Viehmann[1], Adrian Krone[1], Niklas Golchert[1], Yusaku Terao[1], Catmarna Küstner-Wetekam[1], Lutz Marder[1], Arno Ehresmann[1], Noelle Walsh[2], Antti Kivimäki[2], and Andreas Hans[1] — [1]Institut für Physik und CINSaT, Universität Kassel, Heinrich-Plett-Str. 40, 34132 Kassel, Germany — [2]MAX IV Laboratory, Lund University, Fotongatan 8, 224 84 Lund, Sweden

Interatomic Coulombic Decay (ICD) is an energy-transfer process in weakly bound matter, typically assumed to act dominantly between nearest neighbors. Following recent theoretical prediction, we report experimental evidence for non ICD. Using synchrotron radiation to ionize the Ne 2s shell in Ne clusters and electron-electron coincidence measurements with a time-of-flight spectrometer, we present ICD electron spectra that isolate decay channels beyond the nearest-neighbor shell. The data show qualitative agreement with the expected non-local ICD mechanism. Measurements were performed using the Transverse Resonance Island Buckets (TRIBs) at the MAX IV synchrotron (Lund, Sweden), enabling simultaneous multibunch and pseudo-single-bunch operation at different beamlines by adjusting the respective optics to distinct electron orbits.

A 21: Poster – Atomic Systems in External Fields

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

A 21.1 Wed 17:00 Philo 1. OG

Revealing emergent many-body phenomena by analyzing large-scale space-time records of monitored quantum systems — •Marcel Cech[1], Cecilia De Fazio[1], María Cea[2,3], Mari Carmen Bañuls[2,3], Igor Lesanovsky[1,4], and Federico Carollo[5] — [1]Universität Tübingen, Tübingen, Germany — [2]Max-Plank-Institut für Quantenoptik, Garching, Germany — [3]Munich Center for Quantum Science and Technology (MCQST), München, Germany — [4]University of Nottingham, Nottingham, United Kingdom — [5]Coventry University, Coventry, United Kingdom

Recent advances in quantum simulators permit unitary evolution interspersed with locally resolved mid-circuit measurements. This paves the way for the observation of large-scale space-time structures in quantum trajectories and opens a window for the *in situ* analysis of complex dynamical processes. We demonstrate this idea using a paradigmatic dissipative spin model [1], which can be implemented, e.g., on Rydberg quantum simulators. Here, already the trajectories of individual experimental runs reveal surprisingly complex statistical phenomena. In particular, we exploit free-energy functionals for trajectory ensembles to identify dynamical features reminiscent of hydrophobic behavior observed near the liquid-vapor transition in the presence of solutes in water. We show that these phenomena are observable in experiments and discuss the impact of common imperfections, such as readout errors and disordered interactions.

[1] M. Cech, *et al.*, arXiv:2507.00944 (2025)

A 21.2 Wed 17:00 Philo 1. OG

Interaction between Poincaré light and atoms — •Shreyas Ramakrishna[1,2] and Stephan Fritzsche[1,2] — [1]Helmholtz Institute Jena, Germany — [2]Friedrich-Schiller University Jena, Germany

This poster discusses the physics underlying the interaction between a Poincaré beam and an optically polarized atomic medium in the presence of a constant magnetic field. Our investigation reveals that the absorption profile of the Poincaré beam exhibits axial asymmetry. This asymmetry depends sensitively on the relative orientation of the pump and probe light fields with respect to the quantization axis, as well as on the strength of the magnetic field. To illustrate these findings, we choose the incoming radiation drives an electric dipole transition, $F_g = 1$ to $F_e = 0$ in rubidium atoms subjected to various magnetic field strengths.

A 21.3 Wed 17:00 Philo 1. OG

Suppression and revival of Floquet-Feshbach resonances — •Louisa Marie Kienesberger, Alexander Guthmann, Felix Lang, Vicente Baca, David Lang, Eleonora Lippi, and Artur Widera — RPTU University

Resonant scattering is a central concept in physics, providing a powerful tool on interaction dynamics from nuclear reactions to ultracold quantum gases. In ultracold atomic systems, magnetically tunable Feshbach resonances enable precise and flexible control over interaction strengths. Recently, we demonstrated that Floquet engineering of two-body interactions via periodically modulated magnetic fields enables the creation of additional, tunable Feshbach resonances [1].

In this contribution, we investigate the behaviour of these Floquet-Feshbach resonances as a function of the modulation strength and identify a characteristic Bessel-function dependence, where the order of the Bessel function corresponds to the order of the Floquet-Feshbach resonance. These Bessel functions define how the widths and amplitudes of the individual Floquet-Feshbach resonances vary with modulation amplitude and frequency, providing a simple handle to enhance or suppress specific resonances. Furthermore, these studies offer insight into Floquet-induced scattering dynamics and support the tailored control of atomic interactions required for quantum simulations of complex many-body systems and the exploration of exotic quantum phases.

[1] A. Guthmann, F. Lang, L. M. Kienesberger, S. Barbosa, and A. Widera, Floquet engineering of Feshbach resonances in ultracold gases, Science Advances 11, eadw3856 (2025).

A 21.4 Wed 17:00 Philo 1. OG

Mechanical squeezed Kerr oscillator based on a tapered ion trap — Bogomila Nikolova[1], Moritz Gob[2], Kilian Singer[2], and •Peter Ivanov[1] — [1]Sofia University, Bulgaria — [2]University of Kassel, Germany

We propose a theoretical description of a mechanically squeezed Kerr oscillator with a single ion in a tapered trap. We show that the motion coupling between the axial and radial modes caused by the trap geometry leads to Kerr nonlinearity of the radial mode with magnitude controlled by the trap frequencies. This allows the realization of non-Gaussian quantum gates, which play a significant role in the universal set of continuous variable quantum gates. Furthermore, we show that, because of the nonlinearity of the ion trap, applying an off-resonant time-varying electric field along the trap axis causes a motion squeezing of the radial mode. Finally, we discuss the motion mode frequency spectrum of an ion crystal in a tapered trap. We show that the frequency gap between the motion modes increases with trap nonlinearity, which benefits the realization of faster quantum gates.

A 21.5 Wed 17:00 Philo 1. OG

High-fidelity multistate Stimulated Raman adiabatic passage via parallel eigenenergies — •Julian K. Dimitrov and Nikolay V. Vitanov — Center for Quantum Technologies, Department of Physics, Sofia University, James Bourchier 5 blvd., 1164 Sofia, Bulgaria

We present a new approach to high-fidelity multistate Stimulated Raman adiabatic passage (STIRAP). Techniques that optimize multistate STIRAP have been proposed before and they require using additional (shortcut) fields. Here we propose an optimization which does not require additional fields but pulse shaping only. The optimization is based upon the concept of quasi-parallel eigenenergies, which are known to suppress nonadiabatic transitions between two states. It is shown analytically how the parallelization criterion imposes certain time-dependent pulse shapes of the driving fields. Similar to parallel three-level STIRAP, proposed earlier, the parallel multistate STIRAP is robust to errors in the driving fields and the detunings while leaving the intermediate states unpopulated in the adiabatic limit. Moreover, this improvement of fidelity does not require prohibitively large pulse areas. We manage to enhance the STIRAP fidelity by up to 5 orders of magnitude thereby making multistate STIRAP suitable for quantum information processing. We anticipate applications in atomic clocks and atom optics.

A 22: Poster – Attosecond Physics (joint session A/MO)

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

A 22.1 Wed 17:00 Philo 1. OG

New 1D atomic model potential for more accurate high-order-harmonic-generation spectra — •Krisztina Sallai[1,2], Szabolcs Hack[1,2], Szilárd Majorosi[1], and Attila Czirják[1,2] — [1]The Extreme Light Infrastructure ERIC | ALPS Facility, Szeged, H-6728, Hungary — [2]University of Szeged, Szeged, H-6720, Hungary

Building on the favourable properties of previously used one-dimensional (1D) atomic model potentials, we introduced a new 1D Gaussian-windowed atomic model potential in [1] for simulating the quantum dynamics of a single active electron atom driven by a strong, linearly polarized near-infrared laser pulse. This new model potential upgraded the accuracy of 1D numerical simulations for single-atom high-order-harmonic-generation (HHG) spectra under commonly used driving laser pulse parameters. By combining two model potentials, we define the Gaussian windowed soft-core Coulomb (GSC) potential (with a =2.551 and b = 2) as

$$V^{1D}_{GSC}(z) = V^{1D}_{SC}(z)\exp(-(z/a)^2) + V^{1D}_{MSC}(z)\left(1 - \exp(-(z/b)^2)\right).$$

The GSC potential offers an outstanding balance of accuracy and computational efficiency, enabling TDSE simulations that generate reliable HHG spectra within minutes in the $1.26 \times 10^{14} - 6.88 \times 10^{14}\, W/cm^2$ peak intensity range. Our research suggests that the GSC potential performs best when the Keldysh parameter is within $0.45 \leq \gamma \leq 1$ and the 1D ground state population loss simulated with the GSC potential, is not greater than 0.6 at the end of the laser pulse, which is well in line with most GHHG methods.

References: [1] K Sallai et al., Phys. Rev. A 110, 063117 (2024)

A 22.2 Wed 17:00 Philo 1. OG

A rigorous and universal approach for highly-oscillatory integrals in attosecond science — •Anne Weber[1], Job Feldbrugge[2], and Emilio Pisanty[1] — [1]Attosecond Quantum Physics Laboratory, King's College London, WC2R2LS London, UK — [2]Higgs Centre for Theoretical Physics, University of Edinburgh, UK

Light-matter interactions within the strong-field regime, such as high-harmonic generation, typically give rise to highly-oscillatory integrals, which are often solved using saddle-point methods. Not only do these methods promise a much faster computation, but they also inform a more intuitive understanding of the process in terms of quantum orbits, as the saddle points correspond to interfering quantum trajectories (think Feynman's path integral formalism). Despite these advantages, a sound understanding of how to apply saddle-point methods to highly-oscillatory integrals in a rigorous way, and with algorithms which work uniformly for arbitrary configurations and laser drivers, remains lacking. This hinders our ability to keep up with state-of-the-art experimental setups which increasingly rely on tightly-controlled laser waveforms. Here, I will introduce the key ideas of Picard-Lefschetz theory – the foundation of all saddle-point methods – and their implementation. Using high-harmonic generation and above-threshold ionisation as examples, I will show how those ideas provide a robust framework for the fast computation of integrals, as well as a widely-applicable algorithm to derive the relevant semiclassical quantum orbits that underlie the physical processes.

A 22.3 Wed 17:00 Philo 1. OG

Coulomb-corrected reconstruction of ionization and recombination times in high-order harmonic generation — •Mohammad Monfared and Manfred Lein — Institute for Theoretical Physics, Leibniz Universität Hannover, Hannover, Germany

Accurate attosecond-scale measurement of electron dynamics is fundamental to ultrafast science. The orthogonally polarized two-color (OTC) field technique enables the reconstruction of electron ionization and recombination times from high-order harmonic generation (HHG) spectra. However, established retrieval methods often neglect or utilize an oversimplified treatment of the Coulomb interaction, limiting their precision. In this work, we introduce a refined time-retrieval method that significantly improves the accuracy of reconstructing ionization and recombination times in OTC fields. We identify that one of the main time-retrieval equations, namely the condition used in earlier works to maximize the harmonic intensity as a function of the two-color delay, is only approximate and replace it with a more accurate stationarity equation. In addition, we incorporate Coulomb effects beyond the simple approximation of an instantaneous momentum kick by numerically integrating the Coulomb force and potential along the classical electron trajectories, providing a more physically consistent correction. We benchmark our method against exact time-dependent Schrödinger equation simulations and the analytical R-matrix theory. Our results demonstrate a substantial improvement in the accuracy of the retrieved ionization times, achieving near-perfect agreement with benchmark models especially for high-frequency probe fields.

A 22.4 Wed 17:00 Philo 1. OG

Technical performance of the upgraded XUV and soft X-ray split-and-delay unit at FLASH1 — •Matthias Dreimann, Michael Wöstmann, and Helmut Zacharias — Center for Soft Nanoscience, Universität Münster

The split-and-delay unit at FLASH1, in operation since 2007, has been upgraded to meet the advances of increasing photon energies of FLASH1 since then. With the original design first experiments were performed in 2007 and the SDU was permanently incorporated in the BL2 at FLASH1 in 2010. The upgrade increases the spectral range of the SDU from former hv = 250 eV to now hv = 750 eV. Two different mirror coatings achieve a high transmission in the whole spectral range. The design is based on a three dimensional beam path and allows choosing the propagation via two sets of mirrors with different coatings. A carbon coating allows a total transmission on the order of $T > 0.74$ for photon energies between hv = 30 eV and hv = 200 eV at a grazing angle of 3.0° in the variable beam path. In the fixed beam path a shallower grazing angle of 2.5° is used, which yields a total transmission of $T > 0.79$. An Ni coating can be used to additionally cover a range up to hv = 750 eV. This results in a total transmission of typically $T = 0.4$ in the variable and $T = 0.3$ in the fixed beam path. The delay range of the new set-up is -1 ps $< t <$ +9 ps with a subfemtosecond temporal delay.

A 22.5 Wed 17:00 Philo 1. OG

Attosecond Streaking Spectroscopy: From Gas-Phase Dynamics to Adsorbed Molecules — •Ron Ducke, Sven-Joachim Paul, Maximilian Pollanka, Christian Schröder, Pascal Freisinger, Andreas Duensing, Reinhard Kienberger, and Maximilian Forster — Technische Universität München, Garching, Germany

We present the attosecond streaking setup established in our laboratory, designed to investigate time-resolved photoemission dynamics with high temporal precision. By using attosecond pulses, generated by HHG, we successfully determined absolute photoemission delays across a broad range of systems. In the gas phase, we review key results including absolute delays in the valence range of water and comparative studies of isosteric molecules, which elucidate the link between electronic structure and emission timing. Furthermore, a systematic analysis of iodoalkanes reveals the significant influence of the molecular environment on the emission from the iodine atom. Moving beyond the gas state, we discuss the photoemission delays of molecules adsorbed on crystal surfaces. Investigations of iodomethane and iodoethane on Pt(111) demonstrate how molecular orientation and surface interactions affect the measured delays compared to the gas phase. Finally, we present an outlook on our current measurements regarding e.g. Xenon and Neon.

A 22.6 Wed 17:00 Philo 1. OG

Phase control in XUV-assisted high-order harmonic generation — •Zeinab Hardani and Manfred Lein — Leibniz University Hannover, Institute of Theoretical Physics,30167 Hannover, Germany

We investigate high-order harmonic generation (HHG) driven by a combined extreme-ultraviolet (XUV) pulse combined with a strong infrared (IR) laser field. Single-photon absorption of the XUV pulse releases the electron with well-defined initial conditions, while the IR field governs its motion in the continuum and its recombination with the parent ion. We evaluate the harmonic phase in XUV-assisted HHG and identify four main contributions: the strong-field phase, the Coulomb phase from the long-range potential, the recombination phase from the transition dipole, and an additional ionization phase associated with XUV-assisted emission. To quantify these contributions, we solve the one-dimensional time-dependent Schrödinger equation (TDSE) for an atomic model driven by combined IR+XUV fields and compare the extracted phase with the theoretical methods: strong-field approximation, analytical R-matrix, and scattering-theory predictions. In addition, we employ a classical model including the Coulomb potential and the XUV-imposed initial velocity to obtain ionization and recollision times, these recollision times agree with those inferred from the TDSE. Overall, we show that the XUV field shifts ionization and recombination to later times, thereby delaying harmonic emission and reshaping the phase of attosecond electron trajectories in agreement with both quantum simulations and classical modeling, and offering a flexible route to control XUV-triggered HHG in time.

A 22.7 Wed 17:00 Philo 1. OG

Building a high-resolution XUV attosecond transient absorption spectrometer to observe time-dependent effects in atoms and molecules — •Noah L. Wach[1], Gergana D. Borisova[1,2], Christian Ott[1], and Thomas Pfeifer[1] — [1]Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg, Germany — [2]Department of Physics, Lund University, P.O. Box 118, 22100 Lund, Sweden

Attosecond transient absorption spectroscopy (ATAS) has been extensively used to observe ultrafast electronic as well as vibrational dynamics in atoms and molecules[1,2]. Here, a combination of intense NIR femtosecond pulses, together with a high-harmonic-generated XUV pulse derived from them, is used to probe and control the systems quantum dynamics. We develop a new experimental setup, SHARP-XUV, which combines a conventional ATAS setup with a high-resolution XUV spectrometer in a Rowland configuration featuring a 3-meter arm length. This design is aimed to obtain an energy resolution of more than 10 000. Together with a time resolution of about a hundred attoseconds, we will be able to observe the complex dynamics where electronic or vibrational resonances lie extremely close and are hard to resolve with conventional XUV spectrometers. This setup will enable us to study the laser control of the overlapping series of highly doubly excited helium states as well as the laser-driven dynamics of increasingly closely spaced transitions near an ionization threshold.

[1] C. Ott et al., Nature 516, 374-378 (2014)
[2] G. Borisova et al., Phys. Rev. Research 6, 033326 (2024)

A 23: Poster – Interaction with Strong or Short Laser Pulses (joint session A/MO)

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

A 23.1 Wed 17:00 Philo 1. OG

Bound-free electron-positron pair production in combined Coulomb and constant crossed electromagnetic fields — •Svea Remme, Alexandra Eckey, Selym Villalba-Chavez, Alexander B. Voitkiv, and Carsten Müller — Institut für Theoretische Physik I, Heinrich-Heine-Universität Düsseldorf

Bound-free electron-positron pair production by a highly charged bare ion in the presence of a strong constant crossed electromagnetic field is studied. We apply two different methods to calculate the pair production rate: (i) a quasiclassical tunneling theory and (ii) a strong-field approximation, both equipped with appropriate Coulomb correction factors. The resulting rate is shown to depend nonperturbatively on both the Coulomb field of the ion and the constant crossed field.

A 23.2 Wed 17:00 Philo 1. OG

Time-delay in Tunnel-Ionization and barrier-suppression ionization — •Ossama Kullie — Theoretical Physics, Institute for Physics, Department of Mathematics and Natural Science, University of Kassel, Germany.

In previous work, we presented tunnel-ionization model [1,2], in which we showed a real tunneling time-delay picture that agrees well with the experimental results in the adiabatic [1] and nonadiabatic [3] field calibrations. In addition, we showed that the tunnel-ionization time exhibits a universal behavior consistent with Winful's unified tunneling picture [4], which amounts to determine the barrier time-delay with good agreement with the experimental result and it corresponds to the interaction time [5]. Barrier-suppression ionization is a phenomenon in strong-field physics where a high-intensity laser field completely flattens the potential barrier, allowing an electron to escape an atom or molecule without the need for quantum tunneling. In the present work, based on our model [1] and the findings of recent work [5], we extend our time-delay model to include the regime of barrier-suppression ionization. [1] O. Kullie, Phy. Rev. A 92, 052118 (2015). [2] O. Kullie, Annals of Physics 389, 333 (2018). [3] O. Kullie and I. A. Ivanov, Annals of Physics 464, 169648 (2024). [4] H. Winful, Phys. Rev. Lett. **90**. 023901 (2003). [5] O. Kullie, J. Phyis. Commun. 9, 015003, (2025).

A 23.3 Wed 17:00 Philo 1. OG

Investigation of Interactions at relativistic laser intensities with Highly Charged Ions — •Stefan Ringleb[1], Manuel Vogel[2], Sugam Kumar[3], Stefan Kiesel[4], and Thomas Stöhlker[1,2,4] — [1]Friedrich-Schiller Universität Jena — [2]GSI Helmholtzzentrum für Schwerionenforschung Darmstadt — [3]Inter-University Accelerator Centre, New Delhi, India — [4]Helmholtzinstitut Jena

Interaction of high-intensity lasers with highly charged ions is a widely explored field theoretically. In contrast, there is still a lack of experimental data on the interaction with highly charged ions, with most experiments to date focusing on high-intensity laser ionization of initially neutral gases. In our working HILITE setup, highly charged ions prepared for ion targets in a defined initial quantum state containing between 5,000 and 25,000 ions. We have elaborated techniques for ion-cloud preparation regarding fast ion cooling in axial direction and ion number. We have investigated the radial self arrangement of the ions to maximise the ion number in the laser volume. Currently, an experiment at the 200 TW femtosecond Laser system JETi200 is in operation to investigate the ionization dynamics at relativistic laser intensities. In the experiment, we will focus on hydrogen-like ions which can be described precisely by theory. This will also allow for the intensity determination in the laser focus, as this is the less accurate determined parameter in laser experiments. The setup is designed to enable experiments of laser-ion interaction with high accuracy and allow the test of laser-ionisation models for many-electron systems.

A 24: Poster – Interaction with VUV and X-ray Light (joint session A/MO)

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

A 24.1 Wed 17:00 Philo 1. OG

Temporal evolution of x-ray fluorescence of highly charged xenon ions under FEL irradiation — •Moritz J. Grunwald-Delitz[1], Thomas M. Baumann[1], Michael Meyer[1], Johan Söderström[2], and Jan-Erik Rubensson[2] — [1]European XFEL, Holzkoppel 4, 22869 Schenefeld, Germany — [2]Department of Physics and Astronomy, Uppsala University, Box 516, 751 20 Uppsala, Sweden

We present the results of x-ray emission spectroscopy (XES) measurements on the interaction of intense x-ray free-electron laser pulses with xenon gas, aiming for a state-resolved exploration of non-linear multi-photon ionization and excitation processes. We utilize the 1D-imaging spectrometer [M. Agåker et al., J. Synchrotron Radiat., 31(5), 2024.] at the SQS instrument of European XFEL and its gas cell sample environment, which allows for studying Xe at a few mbar, a regime where, besides photon-driven processes, electron collisions start to contribute to the highly charged ion and excited state populations. Interestingly, this was not observed during prior studies on neon gas under similar conditions [S.-K. Son et al., Phys. Rev. A, 112(5), 2025, L051101.]. Our measurements monitor the evolution of these contributions over several nanoseconds after the XFEL pulse, revealing a distinct double-peak structure in the time-of-flight distribution.

A 24.2 Wed 17:00 Philo 1. OG

Parametric Mössbauer Radiation Generated by the European XFEL Electron Beam — •Ze-an Peng, Christoph H. Keitel, and Jörg Evers — Max-Planck-Institut für Kernphysik, Heidelberg, Germany

The ultranarrow nuclear resonances of Mössbauer isotopes enable precision spectroscopy and x-ray quantum optical applications, yet they make strong resonant excitation difficult with conventional x-ray sources. Parametric x-ray radiation (PXR), produced when relativistic electrons traverse a crystal, provides a high-quality, low-divergence x- ray source. When the crystal contains Mössbauer nuclei, spectrally narrow parametric Mössbauer radiation (PMR) can be generated under suitable conditions. We develop a general dynamical diffraction theory of PMR for arbitrary emission directions, covering both the conventional diffraction geometry and the more extreme grazing specular diffraction geometry. We show that the new geometry can substantially enhance PMR intensity due to specular diffraction of the electron virtual-photon fields at the crystal surface, which allows radiation to form predominantly outside the crystal and thus avoids strong absorption. We further apply the framework to superradiant PMR (SPMR) generated by microbunched XFEL electron beams, and introduce how superradiant amplification and geometric optimization combine to boost emission. The scheme applies broadly to PXR and PMR from both incoherent continuous- wave electron beam and the XFEL electron bunches, offering a pathway toward intense, coherent, and spectrally narrow Mössbauer x-ray sources.

A 24.3 Wed 17:00 Philo 1. OG

Microcrystalline and thin layers for precision spectroscopy — •Simon B. Diewald[1], Jonas Stricker[1,2], Dennis Renisch[1,2], and Christoph E. Düllmann[1,2,3] — [1]JGU Mainz, Deutschland — [2]HI Mainz, Deutschland — [3]GSI Darmstadt, Deutschland

$^{232}ThF_4$ is a promising host material for high-precision spectroscopy experiments related to the realization of a solid-state nuclear clock based on the ^{229m}Th isomer. We present a compact method for producing thin and microcrystalline $^{232}ThF_4$ layers on silicon, CaF_2, MgF_2, and stainless-steel substrates via thermal evaporation in an ohmic furnace. The produced layers were characterized regarding their homogeneity and provide samples suitable for future high-precision vacuum-ultraviolet spectroscopy. The method provides homogeneous samples suitable for various high-precision spectroscopy and nuclear-physics applications.

A 24.4 Wed 17:00 Philo 1. OG

Accessing ultrafast electron dynamics with single-shot single-particle diffraction imaging and spectroscopy — •Indrani Dey, Jasper Boultwood, José gómez Torres, Frederic Ussling, Yves Acremann, Isabelle Bolliers, Ehsan Hassanpour Yesagi, Linos Hecht, Katharina Kolatzki, Mario Sauppe, Simon Wächter, Changji Pan, Jannis Lehmann, Alessandro Colombo, Björn Senfftleben, and Daniela Rupp — Nanostructures and Ultrafast X-Ray Science, ETH Zurich

Ultrafast electron dynamics are in principle imprinted in diffraction patterns of single nanoparticles but they are difficult to extract. We have developed high-harmonic generation based single-shot single-particle diffractive imaging in the lab with excellent temporal stability and resolution. To gain access to ultrafast laser-driven changes in the electronic properties of an isolated nanoparticle, also the spectral distribution of the diffracted light needs to be recorded, as it reflects the static and dynamic interaction of the intense XUV pulse with the target. It is also crucial for accurate phase retrieval and structural reconstruction, as multi-harmonic contributions blur fine details. We discuss the design and setup for simultaneous recording of single-shot diffraction patterns and spectrum of free-flying particles and present first results. The development of Coherent Diffraction Imaging and Spectroscopy has the potential to enable also novel XFEL-based experiments with few- and sub-femtosecond pulses.

A 25: Poster – Cluster and Nanoparticles (joint session MO/A)

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

A 25.1 Wed 17:00 Philo 1. OG

Penning ionization and direct photoionization of Mg and Na doped in helium nanodroplets — •Rajni Rajni[1], Narcis-Silviu Blaj[1], Asbjorn Ornemark Lagdsmand[1], Marcel Mudrich[1], Ltaief L. Ben[2], Niklas Scheel[2], and Henrik Pedersen[2] — [1]Institute of Physics, University of Kassel, D-34132 Kassel, Germany — [2]Department of Physics and Astronomy, Aarhus University, 8000 Aarhus C, Denmark

We investigate the direct photoionization and Penning ionization of alkali (Na) and alkaline-earth metals (Mg) embedded in superfluid helium nanodroplets under irradiation with extreme ultraviolet (XUV) synchrotron radiation that resonantly excites the He droplets. Helium is a well-suited system for studying indirect ionization processes due to the simple electronic structure of He, well-resolved electron spectra, weak interaction with embedded species, efficient pick up of molecules and controlled aggregation inside the nanodroplets. We measured spectra of all electrons and of electrons recorded in coincidence with specific ions for He nanodroplets doped with Mg and Na atoms. For Na, the Penning ionization electron spectrum is well resolved but shifted due to attractive interaction of the Na atom and the excited He* (short-range interatomic Coulombic decay). For Mg, we observe a pronounced enhancement of shake-up ionization where an excited Mg^+ ion is produced in the Penning process. Shake-up states are only weakly present in direct photoelectron spectra.

A 25.2 Wed 17:00 Philo 1. OG

Tracking Microhydration of Salt Molecules in Helium Nanodroplets and Commissioning a New Nanoparticle Injector System — •Mikkel Mortensen[1], Niklas Scheel[2], Marcel Mudrich[2], Henrik B. Pedersen[2], and Ltaief B. Ltaief[2] — [1]Institute of Physics, Kassel University — [2]Department of Physics and Astronomy, Aarhus University

The solvation of NaCl molecules in water, is an important process in chemistry. However, microscopic structures and energetics of the hydration complexes remain to be investigated. A recent study has quantified the number of water molecules needed, to form a complete hydration shell around NaCl in helium nanodroplets using Penning Ionization Electron Spectroscopy (PIES)[1]. Building upon this study, we investigate the microhydration dynamics of KBr, NaBr, and NaCl under comparable conditions at the XUV synchrotron light source, ASTRID 2. Our PIES measurements aim to investigate how different ionic constituents affect hydration structure and stability.

Furthermore, we are commissioning a new nanoparticle injector based on an aerodynamic lens system for producing aerosol beams of salt nanoparticles. This development will allow us to do experiments on salt hydration and electron spectroscopy in aerosols, including interactions with XUV radiation at ASTRID.

[1] L. B. Ltaief et al., submitted (2025), arXiv.2510.22000

A 25.3 Wed 17:00 Philo 1. OG

XUV photoionization of Microhydrated Biomolecules — •Niklas Scheel[1], Ltaief Ben Ltaief[1], Henrik B. Pedersen[1], and Marcel C. Mudrich[2] — [1]Department of Physics and Astronomy, Aarhus University, 8000 Aarhus C, Denmark — [2]Institute of Physics, University of Kassel, 34132 Kassel, Germany

Microhydrated biomolecules serve as valuable model systems for studying radiophysical processes in biologically relevant complexes, offering insights into the mechanisms of radiation damage in biological tissue. In this work, we present photoelectron-photoion coincidence (PEPICO) spectra of XUV-irradiated microhydrated thymine and uracil clusters, measured using the electron ion double-imaging endstation XENIA[1] at the ASTRID2 synchrotron.

We investigate outer-valence photoionization, confirming that attached water molecules stabilize the DNA bases against fragmentation[2] by acting as an efficient heat bath. At the same time, the data reveal a charge-transfer mechanism from the DNA base to the water: a charge hole initially created on a water moiety ultimately localizes on the DNA base.

Finally, we will present PEPICO spectra recorded at higher photon energies. These measurements probe inner-valence photoionization, where double ionization becomes accessible, leading to pronounced fragmentation and involving Intermolecular Coulombic Decay (ICD) as an efficient relaxation pathway.

[1] B. Bastian et al., Rev. Sci. Instrum., 2022, 93, 075110
[2] J. D. Asmussen et al., PCCP, 2023, 25, 24819-24828

A 25.4 Wed 17:00 Philo 1. OG

Novel Apparatus for Synchrotron X-ray Photoelectron Spectroscopy of Size-Selected Gas-Phase Clusters — Lotar Kurti, Phillip Stöcks, Fabian Bär, Lukas Weise, and •Bernd v. Issendorff — Physikalisches Institut, Universität Freiburg, Freiburg, Germany

A newly developed apparatus enables X-ray photoelectron spectroscopy on mass-selected cluster ions at synchrotrons. The heart of this system is a liquid nitrogen-cooled linear Paul trap, where stored cluster ions interact with synchrotron radiation. The emitted electrons are guided by a specially designed magnetic field into a Hemispherical Energy Analyzer, where the photoelectron spectra are recorded. Clusters are produced in a magnetron cluster source, mass-selected using a quadrupole mass spectrometer, and then introduced into the linear ion trap. This setup will allow for element-specific binding energy measurements of core levels and hence detailed insights into the chemical bonding of pure and mixed metal and semiconductor clusters. In this contribution, we present the current status of the new apparatus and some initial commissioning results.

A 25.5 Wed 17:00 Philo 1. OG

Single-shot imaging and modeling of individual water nanodroplets with an intense extreme ultraviolet laboratory source — •Lea Schüpke[1], José Gómez Torres[1], Linos Hecht[1], Frederic Ussling[1], Alessandro Colombo[1], Katharina Kolatzki[1], Indrani Dey[1], Changji Pan[1], Isabelle Bollier[1], Constantin Koch[1], Ehsan Hassanpour[1], Yves Acremann[1], Mario Sauppe[1], Björn Senfftleben[1], Hanchao Tang[2], Arnab Choudhury[2], Bruce Yoder[2], Ruth Signorell[2], and Daniela Rupp[1] — [1]ETH Zürich, DPHYS — [2]ETH Zürich, DCHAB

Our unique high-intensity extreme ultraviolet (XUV) beamline enables flash-imaging of individual free-flying nanoparticles in a lab environment, thus avoiding the severe access limitations of large-scale facilities. We have started to investigate the freezing dynamics of supercooled water droplets between few 100 nm and few μm in diameter. This size range is mostly unexplored due to the lack of suitable imaging methods. In this work, Mie-simulations are discussed that allow to understand subtle changes in the diffracted light distribution caused by aggregate state changes and droplet sizes.

A 25.6 Wed 17:00 Philo 1. OG

Detailed investigation of unexpected photoelectron spectra via angle-resolved spectroscopy of noble metal clusters — •Steve Takouan Tchounga, Lukas Weise, and Bernd von Issendorff — Physikalisches Institut, Albert-Ludwigs-Universität, Freiburg im Breisgau, Germany

Angle-resolved spectroscopy provides an important test of the theoretical description of clusters since these spectra carry more information than the bare electron binding energies. Specifically, the anisotropy of photoelectron spectra depends on the angular momentum state [1, 2].

The presented analysis utilizes the additional information from angle-resolved spectroscopy to gain a better understanding of the electronic structure of the cluster. For Au_{33}^- an electronic shell closing is expected, leading to the opening of a new shell for Au_{34}^-. The angular momentum character of this new shell is not in accordance with a simple shell model.

The Issendorff's model [2] was utilized to gain insight into the character of the orbital involved in the premature shell closing of Cu_{91}^-.

The β parameter curve for this orbital exhibits a clear f-type character, indicating a premature filling of the next shell. The reason for this premature shell closing cannot be identified by this result, but the additional information on the character should help in finding the reason.

[1] Bartels et al., Science, 323, 5919 (2009). [2] Piechaczek et al., Phys. Rev. Lett. 126, 233201 (2021). [3] Bartels et al., Phys. Rev. A 88, 043202 (2013).

A 25.7 Wed 17:00 Philo 1. OG

HHG Coherent Diffraction Imaging of water nanodroplets — •José Gómez Torres[1], David Biner[1], Constantin Koch[1], Indrani Dey[1], Frederic Ussling[1], Linos Hecht[1], Yves Acremann[1], Isabelle Bollier[1], Alessandro Colombo[1], Ehsan Hassanpour[1], Katharina Kolatzki[1], Changji Pan[1], Mario Sauppe[1], Lea Schüpke[1], Björn Senfftleben[1], Hanchao Tang[2], Arnab Choudhury[2], Bruce Yoder[2], Ruth Signorell[2], and Daniela Rupp[1] — [1]D-PHYS, ETH Zürich — [2]D-CHAB, ETH Zürich

Homogeneous freezing of free-flying water droplets of 1μm radius and smaller remains largely not understood due to the resolution limit of optical imaging. A change in freezing dynamics is expected in respect to droplets over 10μm [1], but no experimental study has confirmed this. Ice nucleation rates are also uncertain, with previous studies not agreeing on a compatible value [2]. Using intense XUV pulses from our tabletop HHG source, we obtain single-shot diffraction patterns of individual nanodroplets injected using an aerodynamic lens, to investigate possible morphology changes related to freezing. Here, the first results from this measurement are shown.

[1] Buttersack, T et al., JPCB 120 (2016): 504

[2] Amaya, A. and Wyslouzil, B., J. Chem. Phys. 148.8 (2018)

A 25.8 Wed 17:00 Philo 1. OG

High-Resolution Electron Spectroscopy of Doped Helium Nanodroplets with a Hemispherical Electron Analyzer — •Narcis-Silviu Blaj[1], Niklas Scheel[2], Rajni Rajni[1], Asbjørn Laegdsmand[1], Aleksandar Milosavljevic[3], John Bozek[3], and Marcel Mudrich[1,2] — [1]Institute of Physics, University of Kassel, D-34132 Kassel, Germany — [2]Department of Physics and Astronomy, Aarhus University, 8000 Aarhus C, Denmark — [3]Soleil Synchrotron, 91190 Saint-Aubin, France

Helium nanodroplets (HNDs) have mostly been used as inert cryomatrices for spectroscopy of embedded molecules and clusters.

We performed the first high-resolution X-ray photoelectron spectroscopy (XPS) measurements of pure and doped helium nanodroplets at the PLEIADES beamline of SOLEIL Synchrotron using a hemispherical electron analyzer (HEA). In particular, we explored droplets doped with krypton and argon. The formation of Ar and Kr clusters was identified through the appearance of additional low-binding-energy features accompanying the spin-orbit doublets of the atomic photolines (Kr 3d and Ar 2p), in agreement with earlier observations of photoemission from pure small Kr and Ar clusters. We systematically recorded XPS spectra as a function of photon energy, droplet size, and doping level, allowing us to study the evolution of spectral line shifts and intensity ratios between atomic and cluster-specific components.

In addition, we plan further experiments at SOLEIL as well as at other synchrotron facilities to explore a wider range of photon energies, dopants, and cluster conditions.

A 26: Poster – Ultracold Matter (joint session Q/A)

Bosons; Fermions; Rydberg Systems; Experimental Methods

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

A 26.1 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.

A 26.2 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.

A 26.3 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.

A 26.4 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.

A 26.5 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.

A 26.6 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).

A 26.7 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.

A 26.8 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)

A 26.9 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.

A 26.10 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)

A 26.11 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.

A 26.12 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.

A 26.13 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.

A 26.14 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.

A 26.15 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.

A 26.16 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.

A 26.17 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.

A 26.18 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

A 26.19 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

A 26.20 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).

A 26.21 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)

A 26.22 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).

A 26.23 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.

A 26.24 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.

A 26.25 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).

A 26.26 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.

A 26.27 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.

A 26.28 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.

A 26.29 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.

A 26.30 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.

A 26.31 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.

A 26.32 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.

A 27: Ultra-cold Atoms, Ions and BEC III (joint session A/Q)

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

Invited Talk A 27.1 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.

A 27.2 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.

A 27.3 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

A 27.4 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)

A 27.5 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.

A 27.6 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.

A 27.7 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.

A 28: Ultra-cold Plasmas and Rydberg Systems II (joint session A/Q)

Time: Thursday 11:00–13:00 Location: N 2

Invited Talk A 28.1 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 A 28.2 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

A 28.3 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.

A 28.4 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.

A 28.5 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).

A 28.6 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.

A 29: Precision Spectroscopy of Atoms and Ions IV (joint session A/Q)

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

Invited Talk A 29.1 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)

A 29.2 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.

A 29.3 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)

A 29.4 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).

A 29.5 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.

A 29.6 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.

A 29.7 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 6×10^{-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 $\Delta\nu_{\rm BBR} \propto \Delta\alpha T^4$. 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)

A 30: Members' Assembly

Time: Thursday 13:15–14:00 Location: N 25

All members of the Atomic Physics Division are invited to participate.

A 31: Ultra-cold Atoms, Ions and BEC IV (joint session A/Q)

Time: Thursday 14:30–16:30 Location: N 1

A 31.1 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

A 31.2 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.

A 31.3 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.

A 31.4 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)

A 31.5 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.

A 31.6 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.

A 31.7 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.

A 31.8 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.

A 32: Interaction with VUV and X-ray Light I (joint session A/MO)

Time: Thursday 14:30–16:30 Location: N 2

Invited Talk A 32.1 Thu 14:30 N 2

IR-laser induced dressing signatures in helium nanodroplets probed by coherent diffractive imaging — •Tom von Scheven, Björn Kruse, and Thomas Fennel — Institute of Physics, University of Rostock, Albert-Einstein-Str. 23-24, D-18059 Rostock, Germany

Single-shot coherent diffractive imaging (CDI) enables the capture of a full diffraction image of a nanostructure using a single flash of XUV or X-ray light. The resulting scattering image encodes both the geometry and the optical properties of the target. So far, this method has mainly been employed for ultrafast structural characterization [1]. However, CDI can also be utilized to resolve ultrafast optical property changes caused by e.g. transient excitation from nonlinear scattering [2], or by illumination with a second ultra-short laser pulse.

Here, we explore the expected signatures for the latter case theoretically, where simultaneous exposure to a strong IR field can induce transient optical properties. To this end, the effective optical properties, emerging from the laser dressing, are extracted from the dipole response of a local quantum description based on an atom-like solution of the time-dependent Schrödinger equation. In a second step, we apply the well-known Mie-solution, to use the obtained optical properties in order to describe the resulting scattering process at helium nanodroplets and compare the results to recent experiments [3].

[1] I. Barke *et al.*, Nat. Commun. **6**, 6187 (2015)
[2] B. Kruse *et al.*, J. Phys.: Photonics **2**, 024007 (2020)
[3] J. Schäfer-Zimmermann *et al.*, arXiv, 2508.19936 (2025)

A 32.2 Thu 15:00 N 2

Non-Hermitian X-Ray photonics and Exceptional Points in thin-film cavities with Mössbauer nuclei — •Fabian Richter[1], Lars Bocklage[2], Sven Velten[2], Ralf Röhlsberger[2], Xiangjin Kong[3], and Adriana Pálffy[1] — [1]Julius-Maximilians-Universität, Würzburg — [2]DESY, Hamburg — [3]Fudan University, Shanghai

Exceptional Points (EPs) mark non-Hermitian degeneracies where eigenvalues and eigenvectors coalesce, producing enhanced sensitivity to perturbations. While widely explored in optical gain-loss systems [1], translating the physics of EPs to the X-ray regime offers distinct advantages such as superior penetration depth, focusability, and detection efficiency.

Here, we investigate non-Hermitian X-ray photonics in thin-film cavities with ^{119}Sn Mössbauer nuclei under grazing-incidence illumination. In addition to theoretical modeling, we analyze experimental time spectra and reflectivity data recorded at PETRA III. The cavity geometry and incidence angle offer tunable control over dissipation [2], while a magnetic hyperfine field enables steering the system toward EPs. In theory, we identify the magnetic field strengths at which EPs emerge and predict qualitatively distinct features in the simulated time spectra. In the experimental time spectra, the situation is more complicated, especially as quadrupole splitting introduces additional spectral structure and increases the complexity of the eigenvalue problem, yet we are able to reliably extract the relevant signatures.

[1] L. Feng et al., Nature Photon. 11, 752-762 (2017).
[2] J. Evers, K. P. Heeg, Phys. Rev. A 88, 043828 (2013).

A 32.3 Thu 15:15 N 2

Single-shot sorting of Mössbauer time-domain data at X-ray free electron lasers — •Miriam Gerharz and Jörg Evers for the Fe-57 EuXFEL-Collaboration — Max-Planck-Institut für Kernphysik, Heidelberg, Germany

Mössbauer spectroscopy is widely used to study structure and dynamics of matter with remarkably high energy resolution, provided by the narrow nuclear resonance line widths. However, the narrow width implies low count rates, such that experiments commonly average over extended measurement times or many x-ray pulses (“shots”). This averaging impedes the study of non-equilibrium phenomena. It has been suggested that X-ray free-electron lasers (XFELs) could enable Mössbauer single-shot measurements without averaging, and a proof-of-principle demonstration has been reported [1]. However, so far, only a tiny fraction of all shots resulted in signal-photon numbers which are sufficiently high for a single-shot analysis. In [2], we develop a sorting approach which allows us to include all data on a single-shot level, independent of the signal content of the individual shots. It utilizes the presence of different dynamics classes, i.e. different nuclear evolutions after each excitation. Each shot is assigned to one of the classes, which can then be analyzed separately. We envision that our approach opens up new grounds for Mössbauer science and beyond, enabling the study of out-of-equilibrium transient dynamics of the nuclei or their environment.

[1] Chumakov et al., Nature Phys 14, 261-264 (2018)
[2] Gerharz et al., arXiv:2509.15833

A 32.4 Thu 15:30 N 2

Neural networks for diffraction image separation — •Nikita Morozov — European XFEL, Schenefeld, Germany

Newly available soft X-ray two-color FEL pulse mode at European XFEL opens a new path to the structural and plasma studies at the nanometer scale. The first pulse, designated as the pump, characterizes the initial state of the object, whereas the second probe pulse captures the system's evolution following its interaction with the pump. The pulses are separated by a short time interval of less than 1 ps. Because this delay is shorter than the detector acquisition time, the state-of-the-art detectors are unable to capture two independent Coherent Diffractive Imaging (CDI) images corresponding to the pump and probe pulses. Instead, it records a single data frame that contains a superposition of CDIs from both FEL pulses, making it almost impossible to follow the evolution process.

This work presents machine learning-based solutions for separating the overlapping components in such data sets. We propose two methods: the first one is based on diffusion probabilistic models, a recent and powerful approach for image generation, and the second using feed-forward convolutional neural networks to solve the same task.

Ideally, after the image separation task is done, the pump and probe densities could be recovered using standard phase retrieval techniques, allowing the excitation-induced changes to be examined in a time-resolved manner.

A 32.5 Thu 15:45 N 2

Laser-driven electron dynamics in helium nanodroplets retrieved from single-shot diffraction patterns — •B. Senfftleben[1,2,3], A. Colombo[1], A. Hoffmann[2], M. Sauppe[1,2], K. Kolatzki[1,2], B. Langbehn[4], J. Schäfer-Zimmermann[1,2], M. Kretschmar[2], M. Krause[2], T. Nagy[2], M. J. J. Vrakking[2], B. Schütte[2], and D. Rupp[1,2] — [1]ETH Zurich, Switzerland — [2]Max-Born-Institut Berlin, Germany — [3]European XFEL, Schenefeld, Germany — [4]TU Berlin, Germany

Coherent diffraction experiments on single particles using intense X-ray or XUV light sources have revolutionized the structural determination of fragile, short-lived nanoscale samples and their dynamics. However, electronic properties are also inherently encoded in the diffraction patterns, but their extraction requires new analysis methods. In our study, we employed a high-harmonic-generation (HHG) light source to perform NIR-XUV pump-probe experiments at photon energies near strong electronic resonances of helium droplets.

In this presentation, several of our analysis approaches to address challenges related to detection artifacts and the multicolor nature of HHG radiation will be discussed. Moreover, initial findings on ultrafast changes in the optical properties and, thus, on electron dynamics of helium nanodroplets will be presented.

A 32.6 Thu 16:00 N 2

Fast Simulation of Wide-Angle Coherent Diffractive Imaging — •Paul Tuemmler, Julia Apportin, Thomas Fennel, and Christian Peltz — Institute of Physics, University of Rostock 18051, Rostock, Germany

Single-shot coherent diffractive imaging with intense XUV and soft X-ray pulses offers the exciting possibility of retrieving both the 3D structure and optical properties of nanoscale objects from a single diffraction pattern. Achieving this, however, requires an accurate description of the underlying wide-angle scattering and propagation effects, which are significantly more complex than in conventional X-ray diffraction.

In this talk, I will introduce the propagation multi-slice Fourier transform method (pMSFT) [1], a fast and accurate approach for simulating the scattering process in this regime. I will outline its derivation from first principles, introduce a unified physical picture to show its relation to existing methods, and finally present systematic benchmarks demonstrating its superior performance for wide-angle scattering.

[1] P. Tuemmler, et al., Laser Photonics Rev (2025): e02001 https://doi.org/10.1002/lpor.202502001

A 32.7 Thu 16:15 N 2

K-edge core excitation and ionization of singly charged sulfur cations — •Simon Reinwardt[1], Patrick Cieslik[1], Ticia Buhr[2], Alexander Perry-Sassmannshausen[3], Stefan Schippers[3], Alfred Müller[3], Stephan Fritzsche[4,5], Florian Trinter[6], and Michael Martins[1] — [1]Universität Hamburg, Hamburg, Germany — [2]Deutsches Elektronen-Synchrotron (DESY), Hamburg, Germany — [3]Justus-Liebig-Universität Gießen, Gießen, Germany — [4]Friedrich-Schiller-Universität Jena, Jena, Germany — [5]Helmholtz-Institut Jena, Jena, Germany — [6]Fritz-Haber-Institut, Berlin, Germany

Near-edge X-ray absorption spectroscopy on sulfur cations provides important reference data for X-ray telescopes and to investigate tender or soft X-ray induced fragmentation processes on sulfur-containing molecular ions. Using the photon-ion merged-beams technique, implemented at the Photon-Ion Spectrometer at PETRA III [1], we measured relative cross sections for twofold, threefold, fourfold, and fivefold photoionization of singly charged sulfur cations in the photon-energy range from 2460 eV to 2510 eV. To theoretically describe the relative cross sections of the different product charge states, we have calculated decay cascades with the Jena Atomic Calculator [2].

[1] S. Schippers *et al.*, J. Phys. B **47**, 115602 (2014).

[2] S. Fritzsche, Comput. Phys. Commun. **240**, 1 (2019).

A 33: Precision Spectroscopy of Atoms and Ions V (joint session A/Q)

Time: Thursday 14:30–16:30 Location: N 3

A 33.1 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$^+$$-^{172}Yb^+$ Coulomb crystal clock interrogating the ^{1}S$_0$$-^{3}P_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 ^{1}S$_0$$-^{3}P_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.

A 33.2 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 $^{173}Yb^+$.

A 33.3 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.

A 33.4 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.

A 33.5 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)

A 33.6 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.

A 33.7 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)

A 33.8 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).

A 34: Correlation Phenomena

Time: Thursday 14:30–15:15 Location: N 25

A 34.1 Thu 14:30 N 25

Robust detection of entanglement transitions in the projective transverse field Ising model — •Felix Roser[1], Etienne M. Springer[2], Hans Peter Büchler[1], and Nicolai Lang[1] — [1]Institute for Theoretical Physics III, University of Stuttgart, Germany — [2]Institute for Theoretical Physics I, University of Stuttgart, Germany

We propose a scalable and noise-resilient protocol for the detection of the entanglement transition in a projective version of the transverse-field Ising model. Entanglement transitions are experimentally difficult to observe due to the inherent randomness of projective measurements which prohibits repeated state preparation, and due to noise in large-scale experimental settings. Our approach combines decoding techniques with classical shadow tomography to overcome both problems. This allows for experimentally accessible upper and lower bounds on the entanglement transition without post-selection or full state tomography. These bounds remain robust under noise and their sharpness is only limited by the noise rate.

A 34.2 Thu 14:45 N 25

Graph neural network models for predicting local electronic properties of disordered correlated electron systems — •Konrad Koenigsmann[1], Ho Jang[1], Peter Schauss[2], and Gia-Wei Chern[1] — [1]Department of Physics, University of Virginia, 382 McCormick Road, Charlottesville, VA 22904, USA — [2]Institut für Quantenphysik, Universität Hamburg, Luruper Chaussee 149, 22761 Hamburg, Germany

The rapid development of machine learning (ML) methods has opened up many new avenues of research in the field of condensed matter physics by bridging the tradeoff between efficiency and accuracy that is inherent to many numerical methods used for multiscale simulations. Here, we present a scalable ML model that can predict local and short-range electronic and spin properties of disordered correlated electron systems. A novel feature of our model is the use of a graph neural network (GNN). While GNNs have achieved considerable success in a number of fields including quantum chemistry and materials science, their applications in condensed matter physics remain largely unexplored. We tested the model by training on small-system-size determinant quantum Monte Carlo (DQMC) simulations of the square-lattice Anderson-Hubbard model, a paradigmatic system for studying the interplay between disorder and correlations. We find that the model is able to reasonably predict the local and short-range electronic and spin properties of the system. Our results demonstrate the potential and effectiveness of using GNNs for multiscale modeling of disordered correlated electron and other condensed matter systems.

A 34.3 Thu 15:00 N 25

Bell's theorem and non-commutation — •Carsten Held — Nonnenrain 2, 99096 Erfurt, Germany

Bell's theorem, in the form of the CHSH inequality (<ab> + <ab'> + <a'b> - <a'b'> * 2), can be derived using the presupposition that the values of hidden variables are scalars, not vectors. Here the relation of this thought with geometric algebra more generally is explored. Non-commutation appears as a key to understanding the significance of Bell's theorem.

A 35: Cluster and Nanoparticles (joint session MO/A)

Time: Thursday 15:15–16:45 Location: P 105

Invited Talk A 35.1 Thu 15:15 P 105

Charge and electronics in molecule activation by transition metal clusters — •Gereon Niedner-SChatteburg, Nils Wolfgramm, and Christoph van Wüllen — Fachbereich Chemie, RPTU Kaiserslautern-Landau, 67663 Kaiserslautern

Isolated transition metal clusters (TMCs) serve as well established proxys for the characterization of elementary reaction steps and intermediates. The charge states of such clusters are subject of debate ever since. We have developed and applied a cryo trapping technique [1] that allowed us to characterize size selected TMCs and their adsorbates for their kinetic and spectroscopic properties [2-8]. Electronic characterization arose through novel X-ray techniques which we have brought to gas TMCs [9]. We have recently started a systematic quantum chemical survey of electronic effects along the N_2 activating reaction pathways of some selected clusters [10], and the conceptual findings of this survey shall be presented and discussed. [1] 10.1016/B978-0-12-814013-0.00019-3; [3] 10.1039/c5cp00047e; [2] 10.1021/acs.jpcc.6b12167; 10.1063/1.4997403 ; 10.1063/1.4997407; [5] 10.1007/s11244-017-0865-2 ; 10.1080/00268976.2021.1953172; [4] 10.1063/5.0064965 ; 10.1063/5.0064966; [5] 10.1063/5.0075289 ; 10.1063/5.0075286; [7] 10.1039/D0CP06208A ; 10.1063/5.0157218 ; 10.1063/5.0157217; [8] 10.1021/acs.jpclett.8b00093 ; submitted to Helv. Chim. Act. (2025); [9] 10.1103/PhysRevLett.107.233401 ; 10.1039/C5CP01923K ; 10.1063/1.4929482; [10] to be published

A 35.2 Thu 15:45 P 105

Size characterization of doped rare-gas clusters utilizing rotational coherence spectroscopy — •Arne Morlok[1], Grzegorz Kowzan[2], Ulrich Bangert[1], Yilin Li[1], Frank Stienkemeier[1], and Lukas Bruder[1] — [1]University of Freiburg, Institute of Physics, Hermann-Herder-Straße 3, 79104 Freiburg, Germany — [2]Nicolaus Copernicus University in Torun, Institute of Physics, Grudziadzka 5, 87-100 Torun, Poland

A prominent challenge in spectroscopy is to investigate individual molecules or their aggregates in a well-defined and controlled environment. This goal can be accomplished with cluster-isolation spectroscopy, a technique in which molecules are isolated in or on the surface of rare-gas clusters. A complication of this technique is that the clusters, which are produced in a supersonic expansion, do not have a uniform size but follow a broad size distribution dependent on the expansion conditions. Although semi-empirical scaling laws based on the expansion parameters have been derived in order to predict the mean cluster size, results seem to underestimate the actual cluster size in comparison with experimentally determined size distributions. In this contribution, a novel spectroscopic approach is discussed to determine the mean cluster size of neutral rare-gas clusters. The technique is based on already known methods from rotational coherence spectroscopy. Results suggest a new scaling regime for the mean cluster size in the already established model in a certain parameter range.

A 35.3 Thu 16:00 P 105

Measuring the speed of interatomic Coulombic decay in helium nanodroplets — •Asbjørn Ørnemark Laegdsmand[1], Ltaief Ben Ltaief[2], Eva Klimesova[3], Keshav Sishodia[3], Martin Albrecht[3], and Marcel Mudrich[1] — [1]Institute of Physics, University of Kassel, 34132 Kassel, Germany — [2]Department of Physics and Astronomy, Aarhus University, 8000 Aarhus C, Denmark — [3]ELI Beamlines, The Extreme Light Infrastructure ERIC, Za Radnicí 835, 252 41 Dolní Břežany, Czech Republic

Helium nanodroplets are an interesting *test tube* for many types of interatomic reactions. In this work we have looked at both interatomic Coulombic decay (ICD) and laser-assisted electron scattering (LAES). We have measured the rate of ICD in lithium-doped helium nanodroplets by an EUV-pump NIR-probe scheme.

The nanodroplets are resonantly excited into the 1s 2p ^{1}P state with a 21.6 eV pump pulse and multi-photon ionized with an 1.56 eV probe pulse. ICD and LAES electrons are detected with in a magnetic bottle electron spectrometer. Arrival of the probe pulse ionizes most of the 1s 2p ^{1}P He, quenching the ICD process. Thus by varying the time delay between pump and probe we measure the speed of the ICD for different droplet sizes.

From the resulting electron spectra we distinguish several ionization pathways, such as ICD, LAES and above threshold ionization. We model the dynamics of the different pathways by rate equations and estimate their contribution to the total electron yield as a function of pump-probe delay time.

A 35.4 Thu 16:15 P 105

An optical laser blade setup for the detection of isolated nanoparticles — •Constantin Koch[1], José Gómez Torres[1], David Biner[1], Indrani Dey[1], Frederic Ussling[1], Linos Hecht[1], Yves Acremann[1], Isabelle Bollier[1], Alessandro Colombo[1], Ehsan Hassanpour[1], Katharina Kolatzki[1], Changji Pan[1], Mario Sauppe[1], Lea Schüpke[1], Björn Senfftleben[1], Hanchao Tang[2], Arnab Choudhury[2], Bruce Yoder[2], Ruth Signorell[2], and Daniela Rupp[1] — [1]D-PHYS, ETH Zurich — [2]D-CHAB, ETH Zurich

Coherent diffraction imaging (CDI) of free-flying water nanodroplets with our high-intensity extreme ultraviolet (XUV) beamline requires optimal overlap of droplet beam and micrometer-sized XUV focus. So far, this was difficult to achieve because of the small hitrates and large variability of the single-shot signals from XUV diffraction. We present the design, setup and comissioning of an optical laser blade, that makes nanoparticles in the interaction region directly visible and enables a quantitative characterization of the water source. A continuous-wave 450 nm laser is shaped into a thin horizontal laser sheet crossing the droplet beam. The scattered light is recorded with a CMOS camera adapted for vacuum compatibility. We observe clear signal from single droplets in the few hundred nm range and achieved a fast and reliable alignment procedure. The consistent signal also allowed us identify previously overlooked problems in the injector system and to obtain a three-dimensional density distribution of the droplet beam in our vacuum chamber.

A 35.5 Thu 16:30 P 105

Uptake of Ammonia onto Mixed Sodium Sulfate/Bisulfate Cluster Ions Studied in a Cryogenic Ion Trap — •Kevin Li, Yihui Yan, and Jozef Lengyel — School of Natural Sciences, Technical University of Munich, Garching, Germany

Understanding the earliest stages of atmospheric new particle formation (NPF) requires direct measurements on sub-nanometer molecular clusters, yet such studies remain experimentally challenging. To investigate this size range, we have developed a cryogenic ion trap mass spectrometer for kinetic studies with mass-selected cluster ions under multicollisional conditions. The instrument utilizes a ring-electrode ion trap, which enables stable confinement and allows for long reaction times of up to seconds. Therefore, the trap provides a powerful platform for investigating reaction pathways relevant to atmospheric aerosol formation.

In this study, we characterize the performance of the cryogenic ion trap and show its capabilities in a model study measuring uptake of gaseous ammonia onto mixed sodium sulfate and bisulfate ions. We further highlight that investigating mixed multicomponent clusters can reveal synergistic effects in NPF, where different components jointly enhance the uptake efficiency. In mixed sodium sulfate-bisulfate clusters, bisulfate units govern the number of uptaken ammonia molecules, whereas sulfate units control the reaction rate. With these experiments, we demonstrate the instrument's ability to investigate reaction pathways relevant to NPF.

A 36: Poster – Ultra-cold Atoms, Ions and BEC (joint session A/Q)

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

A 36.1 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.

A 36.2 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.

A 36.3 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.

A 36.4 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.

A 36.5 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

A 36.6 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)

A 36.7 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.

A 36.8 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.

A 36.9 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.

A 36.10 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.

A 36.11 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.

A 36.12 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.

A 36.13 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)

A 36.14 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.

A 36.15 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.

A 36.16 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.

A 36.17 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.

A 36.18 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.

A 36.19 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.

A 36.20 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.

A 36.21 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.

A 36.22 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.

A 36.23 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)

A 36.24 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)

A 36.25 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

A 36.26 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.

A 36.27 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.

A 36.28 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.

A 36.29 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.

A 36.30 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.

A 36.31 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.

A 36.32 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.

A 36.33 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.

A 36.34 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)

A 36.35 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.

A 36.36 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.

A 36.37 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.

A 36.38 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.

A 36.39 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.

A 36.40 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.

A 36.41 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).

A 36.42 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.

A 37: Poster – Ultra-cold Plasmas and Rydberg Systems (joint session A/Q)

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

A 37.1 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.

A 37.2 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.

A 37.3 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.

A 37.4 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)

A 37.5 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.

A 37.6 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.

A 37.7 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.

A 37.8 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.

A 37.9 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.

A 38: Poster – Collisions, Scattering and Correlation Phenomena (joint session A/MO)

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

A 38.1 Thu 17:00 Philo 1. OG

Relativistic S-Matrix Calculations of Compton Scattering from Bound Electrons — •Nick Marius Mayer[1,2], Jonas Sommerfeldt[3], and Andrey Surzhykov[1,2] — [1]Technische Universität, Braunschweig, Germany — [2]Physikalisch-Technische Bundesanstalt. Braunschweig, Germany — [3]Laboratoire Kastler Brossel, Paris, France

Compton scattering is a fundamental process in which an incoming photon is inelastically scattered by an electron bound to an atomic nucleus. It finds important applications across many areas of modern science, ranging from medical radiotherapy to X-ray polarimetry. With regard to the latter, we present theoretical analyses of Compton scattering by bound electrons, with special focus on polarization effects. In particular, we discuss calculations based on S-matrix theory. To carry out these calculations, we developed a program that numerically solves the radial Dirac equation accurately for a bound electron in the central nuclear potential, approximated here by a Coulomb potential. Based on this approach, detailed calculations of the doubly differential cross section (DDCS) and the polarization properties of photons scattered by K-shell electrons can be carried out across a broad range of energies and for arbitrary polarization states of the incident photon beam.

A 38.2 Thu 17:00 Philo 1. OG

Observing ergodicity breaking via violations of random matrix theoretic predictions — •Venelin Pavlov[1], Peter Ivanov[1], Diego Porras[2], and Charlie Nation[3] — [1]Center for Quantum Technologies, Department of Physics, St. Kliment Ohridski University of Sofia, James Bourchier 5 blvd, 1164 Sofia, Bulgaria — [2]Institute of Fundamental Physics IFF-CSIC, Calle Serrano 113b, 28006 Madrid, Spain — [3]Department of Physics and Astronomy, University of Exeter, Stocker Road, Exeter EX4 4QL, United Kingdom

Quantum many-body systems can exhibit distinct regimes where dynamics is either ergodic in the sense that it explores an extensive region of available state-space, or non-ergodic, where the dynamics may be restricted or localized. In this work we explore the ability to probe the ergodicity of dynamics via local observables, and use expected results from random matrix theory (RMT) as a benchmark for the ergodic regime. We explore the time evolution of the quantum Fisher (QFI) information in the presence of three different ergodicity breaking mechanisms in a non-integrable spin system, namely, as a consequence of transition to integrability, Many-Body Localization (MBL) and Quantum Many-Body Scars (QMBS). We show that it can be used as a potential witness for transition to non-ergodic behavior. In ergodic quantum systems the QFI exhibits an additional intermediate linear time scaling together with it's typical short-time and long-time quadratic scaling. We show that in all of the three ergodicity breaking scenarios the violation of the random matrix theory predictions leads to the vanishing of the intermediate linear time regime.

A 38.3 Thu 17:00 Philo 1. OG

Analytical determination of multi-time correlation functions in quantum chaotic systems — •Yoana Chorbadzhiyska[1], Peter Ivanov[1], and Charlie Nation[2] — [1]Faculty of Physics, Sofia University "St. Kliment Ohridski", 5 James Bourchier Blvd, Sofia 1164, Bulgaria — [2]Department of Physics and Astronomy, University of Exeter, Stocker Road, Exeter EX4 4QL, United Kingdom

The time-dependence of multi-point observable correlation functions are essential quantities in analysis and simulation of quantum dynamics. Open quantum systems approaches utilize two-point correlations to describe the influence of an environment on a system of interest, and in studies of chaotic quantum system, the out-of-time-ordered correlator (OTOC) is used to probe chaoticity of dynamics. In this work we analytically derive the time dependence of multi-point observable correlation functions in quantum systems from a random matrix theoretic approach, with the highest order function of interest being the OTOC. We find in each case that dynamical contributions are related to a simple function, related to the Fourier transform of coarse-grained wave-functions. We compare the predicted dynamics to exact numerical experiments in a spin chain for various physical observables. We comment on implications towards the emergence of Markovianity and quantum regression in closed quantum systems, as well as relate our results to known bounds on chaotic dynamics.

A 39: 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

A 39.1 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.

A 39.2 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.

A 39.3 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.

A 39.4 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.

A 39.5 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+).

A 39.6 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 1×10^5 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.

A 39.7 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.

A 39.8 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 $5.9 \times 10^{-16}\sqrt{1\,s/\tau}$, 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.

A 39.9 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

A 39.10 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 $5S_{1/2} \rightarrow 5D_{5/2}$ transition at 778.1 nm. The reference features a 72 ml ($67\times32.5\times33\,mm^3$) 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.

A 39.11 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).

A 39.12 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)

A 39.13 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)

A 39.14 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.

A 39.15 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)

A 40: Ultra-cold Atoms, Ions and BEC V (joint session A/Q)

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

Invited Talk A 40.1 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.

A 40.2 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

A 40.3 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.

A 40.4 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).

A 40.5 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.

A 40.6 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.

A 40.7 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.

A 41: Interaction with Strong or Short Laser Pulses II

Time: Friday 11:00–12:45 Location: N 2

Invited Talk A 41.1 Fri 11:00 N 2

State-resolved femtosecond phase control in dense-gas laser-atom interaction enabled by XUV interferometry — •Lina Hedewig[1,2], Carlo Kleine[1], Yu He[1], Felix Wieder[1,2], Christian Ott[1,2], and Thomas Pfeifer[1,2] — [1]Max-Planck-Institut für Kernphysik, Heidelberg, Germany — [2]Ruprecht-Karls-Universität Heidelberg, Germany

We perform an interferometric measurement of an extreme ultraviolet (XUV) pulse passing through an optically dense gas-phase target. Utilizing the interaction with strong and narrow atomic resonances, we demonstrate the femtosecond phase control of the resonant XUV pulse propagation by means of a time-delayed intense near-infrared (NIR) laser pulse. To this end, the concept of spectral interferometry is transferred to the extreme ultraviolet in combination with a computational phase stabilization during post–processing [1]. By doing so, we obtain direct access to the amplitude and phase of the transmitted pulse and hence to the ultrafast dynamics in the target gas.

We benchmark our measurement approach with the singly excited 1s4p Rydberg state of helium to directly reconstruct the temporal structure of the transmitted XUV pulse beyond the single-atom response. An NIR-intensity-controlled variable phase step between 0 and 2 rad is measured on the XUV pulse after passage through the medium, originating from laser-induced transient Stark shifts. [2]

[1] L. Hedewig et al., Opt. Express 33, 48151-48159 (2025)
[2] L. Hedewig et al., Opt. Lett. 50, 3006-3009 (2025)

A 41.2 Fri 11:30 N 2

Phenomenological rate formulas for over-barrier ionization in strong constant electric fields — •Svea Remme[1], Alexander B. Voitkiv[1], Georg Pretzler[2], and Carsten Müller[1] — [1]Institut für Theoretische Physik I, Heinrich-Heine-Universität Düsseldorf — [2]Institut für Laser- und Plasmaphysik, Heinrich-Heine-Universität Düsseldorf

Over-barrier ionization (OBI) of atoms in strong constant electric fields is studied [1]. To develop an intuitive physical picture behind established empirical formulas in the near OBI regime, we extend corresponding tunneling rates by the combined action of the Stark effect and a widened electron emission angle. Furthermore, we present analytical rate formulas in a far OBI regime which closely agree with numerical data. In result, compact rate expressions describing OBI in a broad range of applied field strengths are obtained. They can be useful in numerical laser-plasma simulation codes to describe elementary ionization events.

[1] S. Remme, A. B. Voitkiv, G. Pretzler, and C. Müller, J. Phys. B: At. Mol. Opt. Phys. 58, 195602 (2025)

A 41.3 Fri 11:45 N 2

Deep learning for the retrieval of internuclear motion from photoelectron momentum distributions based on full quantum dynamics — •Nikolay Shvetsov-Shilovski and Manfred Lein — Leibniz Universität Hannover

We retrieve the time-dependent internuclear distance of a dissociating one-dimensional molecule using a neural network that takes photoelectron momentum distributions (PMDs) generated by strong-field ionization as input. The PMDs are calculated by solving the time-dependent Schrödinger equation, with nuclear motion treated fully quantum mechanically. We find that a neural network trained on distributions with fixed bond lengths can recover the time-varying internuclear distance with an absolute error of 0.3 a.u. This opens new perspectives for applying machine learning to real-time visualization of molecular dynamics.

A 41.4 Fri 12:00 N 2

Strong-field ionization and electron diffraction in standing waves — •Tobias Heldt, Jan-Hendrik Oelmann, Lennart Guth, Lukas Matt, Anant Agarwal, Thomas Pfeifer, and José R. Crespo López-Urrutia — Max-Planck-Institut für Kernphysik, Heidelberg, Germany

Achieving the intensities required for strong-field effects, such as multiphoton ionization (MPI), usually relies on kilohertz-rate amplified laser systems. We employ a femtosecond enhancement cavity seeded by a near-infrared frequency comb to reach intensities exceeding $10^{13}\,\mathrm{W\,cm^{-2}}$ at a repetition rate of 100 MHz. The bow-tie cavity supports counter-propagating pulses that form a transient standing wave at the focus. Combined with a gas jet and velocity-map imaging (VMI) [1], this setup allows angle-resolved photoelectron spectroscopy to compare traveling- and standing-wave ionization.

The standing wave doubles the peak intensity and compresses the interaction volume from the Rayleigh length to the < 200 fs pulse-overlap region, enabling momentum imaging without electrostatic refocusing [2]. Furthermore, the spatially periodic ponderomotive potential of a standing wave diffracts electrons (Kapitza-Dirac effect), reshaping the momentum distribution. We aim to time-resolve the diffraction dynamics using an additional interferometer that generates two successive standing waves.

[1] J.-H. Oelmann et al., Rev. Sci. Instrum., 93(12), 123303 (2022).
[2] T. Heldt et al., Opt. Lett. 49, 6825-6828 (2024).

A 41.5 Fri 12:15 N 2

Optimizing the incident electron momentum for resonant three-photon Kapitza-Dirac scattering in bichromatic laser fields — •Ingo Elsner and Carsten Müller — Institut für Theoretische Physik I, Heinrich-Heine-Universität Düsseldorf

Spin dynamics in Kapitza-Dirac scattering of electrons from counter-propagating bichromatic X-ray laser waves is studied theoretically in the resonant Bragg regime [1]. We show that the intrinsic field-induced detuning, which arises in the Rabi oscillation dynamics between initial and scattering electron state, can be compensated by a suitable adjustment of its incident momentum. Analytical formulas of the optimized electron momentum for spin-dependent three-photon Kapitza-Dirac scattering are obtained from simplified model systems in reduced dimensionality.

[1] Ingo Elsner and Carsten Müller, Phys. Rev. A 112, 032215 (2025).

A 41.6 Fri 12:30 N 2

Can the Quantum Supeluminalilty of Tunnel-Ionization be experimentally confirmed? — •Ossama Kullie[1] and Igor Ivanov[2] — [1]Institute for Physics, Department of Mathematics and Natural Science, University of Kassel, Germany. — [2]Department of Fundamental and Theoretical Physics, Australian National University, Australia.

The quantum tunneling time remains the subject of heated debate, and one of its most curious features is the faster-than-light tunneling or quantum superluminality (QS). In our tunnel-ionization model presented in previous work [1,2,3], we showed that tunnel-ionization time-delay exhibits a universal behavior, which amounts to determine the barrier time-delay with good agreement with the experimental result and it corresponds to the interaction time. In the present work, we show that the the tunnel-ionization time-delay for H-like atoms with large nuclear charge can be superluminal, which could be validated experimentally using the attoclock scheme. We discuss the QS in detail for the two experimental calibrations of the field strength (adiabatic and nonadiabatic) of the attoclock and support our result with numerical integration of the time-dependent Schrödinger equation [2]. Our result shows that QS is indeed possible, albeit under somewhat extreme conditions [4]. This raises the question of experimental confirmation of QS. [1] O. Kullie, J. Phyis. Commun. 9, 015003, (2025). [2] O. Kullie and I. A. Ivanov, Annals of Physics 464, 169648 (2024). [3] O. Kullie, Phy. Rev. A **92**, 052118 (2015). [4] O. Kullie and I. A. Ivanov, the quantum suprluminlality of tunnel-ionization. In preparation.

A 42: Atomic Systems in External Fields II

Time: Friday 11:00–12:45 Location: N 3

A 42.1 Fri 11:00 N 3

^{3}Helium magnetometers for high fields — •Peter Blümler[1], Martin Fertl[1], Hans-Joachim Grafe[2], Robert Graf[3], and Werner Heil[1] — [1]Institute of Physics, University of Mainz, 55128 Mainz, Germany — [2]Leibniz Institute for Solid State and Materials Research (IFW), 01069 Dresden, Germany — [3]MPI for Polymer Research, 55128 Mainz, Germany

Low magnetic fields ($< 10^{-12}$ T) can be measured with extreme precision using SQUID or SERF sensors. But at higher fields nuclear magnetic resonance provides the greatest accuracy. Continuous frequency measurements require samples with long coherence times, as obtainable from motionally averaged hyperpolarized nobel gases at a few millibar pressure. ^{3}He is ideal because it can be hyperpolarized by metastability optical pumping, interacts only weakly with its environment, and has an independently determined gyromagnetic ratio. With suitable low-susceptibility containers, extremely long T_2^* times (100 - 200 s) and absolute field measurements are possible. In addition to low-pressure hyperpolarized ^{3}He for ultra-precise magnetometry ($< 10^{-12}$), we have also produced high-pressure (up to 50 bar) thermally polarized ^{3}He-filled cells for applications where optical polarization is impractical. These robust NMR magnetometers can operate from 1 - 300 K, and we describe methods to tune T_1 for rapid sampling across 5 - 300 K (DOI: 10.1063/5.0258240). Overall, ^{3}He magnetometers show strong potential as a new standard for high-precision magnetometry at high magnetic fields.

A 42.2 Fri 11:15 N 3

Drone Integration of an Optically Pumped Magnetometer for Airborne Magnetic Field Sensing — •Ruggero Giampaoli, Ingo Hilschenz, Gunnar Langfahl, Denis Uhland, and Ilja Gerhardt — light & matter group, Institute for Solid State Physics, Leibniz University Hannover, Appelstrasse 2, D-30167 Hannover, Germany

We report on the integration and testing of a compact, alkali-vapor optically pumped magnetometer (OPM) mounted on an unshielded drone platform for magnetic field measurements in flight. The system is intended for use in applications such as mineral exploration, landmine detection, and unexploded ordnance detection. The system features a rubidium-based vapor OPM, which operates at high sampling rates suitable for drone operation. The design focuses on producing a robust, flexible and portable setup, allowing the testing of different configurations and components to ensure seamless integration with the onboard electronics. A flight-test campaign is conducted to assess the performance of the magnetometer in flight and to establish a basis for future refinement toward a full airborne gradiometer configuration. We discuss the integration process, key engineering challenges, and initial test results, outlining progress toward the robust real-world deployment of an optically pumped magnetometer.

A 42.3 Fri 11:30 N 3

High-sensitivity magnetometry with an ensemble of nitrogen-vacancy centers in diamond — •Phani Peddibhotla[1], Shashank Kumar[1], Bapan Debnath[1], Pranit Terse[1], Sakshi Dwivedy[1], Sourav Chatterjee[2], and Pralekh Dubey[1] — [1]Indian Institute of Science Education and Research, Bhopal, India — [2]2TCS Research, TATA Consultancy Services, Kolkata, India

Nitrogen-vacancy (NV) centers are atom-like defects in diamond which enable quantitative magnetic field measurements with high sensitivity and spatial resolution. Using an ensemble of NV centers, we demonstrate magnetic field sensitivities approaching 100 pT per root Hz under ambient conditions, at low frequencies (10 to 100 Hz), and over a large dynamic range. We also discuss applications of NV magnetometry for detection of defects in steel with sub-millimeter spatial resolution.

A 42.4 Fri 11:45 N 3

Towards improvement of the antiproton magnetic moment with phase-sensitive high-fidelity spin spectroscopy — •Bela Peter Arndt for the BASE-Collaboration — Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, D-69117, Heidelberg, Germany — GSI-Helmholtzzentrum für Schwerionenforschung GmbH, Planckstraße 1, D-64291 Darmstadt, Germany

The BASE collaboration is dedicated to the development and application of advanced Penning-trap setups as well as cryogenic superconducting detection systems with single-particle resolution. These methods enable stringent tests of CPT invariance through high-precision measurements on protons and antiprotons. Notable results include the antiproton and proton charge-to-mass ratio with a fractional precision of 16 parts per trillion (ppt), as well as the antiproton g-factor with a fractional precision of 1.5 parts per billion (ppb). This presentation will address challenges associated with spin-state detection in g-factor measurements and will summarize the recent improvements implemented and characterized within the BASE experiment. Particular emphasis will be placed on phase-sensitive frequency-measurement techniques and improved particle cooling, both of which enable new experimental approaches that facilitate sub-100-ppt precision and thus more than a 10-fold improvement in the determination of the antiproton and proton g-factors.

A 42.5 Fri 12:00 N 3

Role of Structured Light in Atomic Magnetometers — •Shreyas Ramakrishna[1,2] and Stephan Fritzsche[1,2] — [1]Helmholtz Institute Jena, Germany — [2]Friedrich-Schiller University Jena, Germany

The use of structured light in atomic magnetometers has attracted considerable attention in recent years. Specifically, we can infer magnetic field properties by analyzing how vector light interacts with a polarized atomic ensemble. In this talk, we will show how we can extend this technique to determine the full vector nature: both direction and strength of an arbitrary constant magnetic field. To do this, we model the interaction between vector Bessel light and Rubidium atoms, focusing on the electric dipole transition from $F_g = 1$ to $F_e = 0$ under the influence of test and reference fields.

A 42.6 Fri 12:15 N 3

Completed two-loop QED calculations for improving the bound-electron g-factor theory — •Bastian Sikora, Vladimir A. Yerokhin, Christoph H. Keitel, and Zoltan Harman — Max Planck Institute for Nuclear Physics, Heidelberg, Germany

The bound-electron g-factor in heavy hydrogenlike ions can be measured with extreme precision. However, the theoretical uncertainty of the g-factor is orders of magnitude larger than the experimental uncertainty in this regime, due to uncalculated QED binding corrections at the two-loop level. This was highlighted in a recent collaboration where experimental and theoretical g-factors of the hydrogenlike tin ion were compared [1].

Taking into account the electron-nucleus interaction exactly, we recently completed the computation of QED Feynman diagrams with two self-energy loops. In our new work, we demonstrate that our results lead to a significant improvement of the total theoretical uncertainty of the bound-electron g-factor in the high-Z regime [2].

Our calculations will enable improved tests of QED in planned near-future experiments with heavy hydrogenlike ions, e.g. at ALPHATRAP and ARTEMIS. Furthermore, our results are relevant for the determination of fundamental constants and nuclear parameters as well as searches for physics beyond the standard model using heavy ions.

[1] J. Morgner, B. Tu, C. M. König, et al., Nature 622, 53 (2023)
[2] B. Sikora, V. A. Yerokhin, C. H. Keitel and Z. Harman, Phys. Rev. Lett. 134, 123001 (2025)

A 42.7 Fri 12:30 N 3

Lithium Faraday Filter — •Maximilian Luka, Yijun Wang, Denis Uhland, and Ilja Gerhardt — light & matter group, Institute of Solid State Physics, Leibniz University Hannover, Germany

We report the first experimental realization and theoretical modeling of a lithium-based Faraday filter operating at 671 nm. Lithium's D-line splitting of approximately 10 GHz, combined with the requirement for operating temperatures above 260 °C, positions the system in a regime that is exceptional among alkali metals. A custom-designed heat pipe was developed to ensure stable lithium vapor generation and to enable the application of longitudinal magnetic fields up to 300 G. To accurately model the filter response, we extended the open-source "ElecSus" library to include lithium's closely spaced D_1 and D_2 transitions, enabling simultaneous simulation of both lines and direct comparison with experimental data. The modified code reproduces the measured spectra with excellent agreement, predicting and confirming a peak transmission exceeding 80 % under optimized conditions. This work expands the family of alkali-metal Faraday filters and provides a framework for lithium-based optical systems, ranging from precision spectroscopy to atmospheric detection of anthropogenic satellite debris.

A 43: Ultra-cold Atoms, Ions and BEC VI (joint session A/Q)

Time: Friday 14:30–16:00 Location: N 1

A 43.1 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)

A 43.2 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.

A 43.3 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.

A 43.4 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.

A 43.5 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.

A 43.6 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.

A 44: Precision Spectroscopy of Atoms and Ions VI (joint session A/Q)

Time: Friday 14:30–15:30 Location: N 3

A 44.1 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).

A 44.2 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.

A 44.3 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.

A 44.4 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.