Q 13: Posters: Quantum Optics and Photonics I

Time: Monday 16:30–18:30 Location: Empore Lichthof

Q 13.1 Mon 16:30 Empore Lichthof

Orbital interaction in the second band of a bipartite optical lattice — •José Vargas, Carl Hippler, and Andreas Hemmerich — Universitaet Hamburg, Hamburg, Germany

We study the orbital interaction dynamics of atoms prepared in the second band of a bipartite square optical lattice. The interplay of band relaxation, condensate formation, and pair exchange dynamics between degenerate condensation points are explored.

Q 13.2 Mon 16:30 Empore Lichthof

A versatile quantum gas machine for the study of dynamics far from equilibrium — •Maurus Hans, Celia Viermann, Marius Sparn, Helmut Strobel, and Markus K. Oberthaler — Kirchhoff- Institut für Physik, Universität Heidelberg, Deutschland

Well controlled experiments with degenerate quantum gases allow for the study of isolated many body systems and their dynamics far from equilibrium that are intractable in purely theoretical studies.

In harmonically trapped quasi one dimensional systems the emergence of universal dynamics has been experimentally observed [1,2]. Our next generation quantum gas setup aims at studying the influence of defects, finite size, dimensionality and interactions in this context. For versatility of the trap geometry and realizing homogeneous systems we implement a vertical pancake trap supplemented by a blue detuned vertical beam shaped by a digital micro-mirror device (DMD). We use 39K which features broad Feshbach resonances and allows for tuning of the interaction strength and quenches to bring the system out of equilibrium.

We give an overview of our setup, the route to BEC and the current status of the experiment.

[1] Prüfer, M. et al., Nature 563, 217-220 (2018) [2] Erne, S. et al., Nature 563, 225-229 (2018)

Q 13.3 Mon 16:30 Empore Lichthof

Weakly interacting Bose-Einstein condensates as quantum baths: (Pre)thermalization and nonequilibrium steady states — •Alexander Schnell and André Eckardt — Max-Planck-Institut für Physik komplexer Systeme, Dresden, Germany

Motivated by recent experimental progress [Phys. Rev. Lett. 121, 130403 (2018)], we study the dynamics of an ideal gas of bosonic impurity atoms which are weakly coupled to a weakly interacting background BEC. Using the standard open-quantum systems framework of Born-, Markov-, and rotating-wave approximation, we find a description of the impurity dynamics in terms of a Pauli rate equation. The rates have the typical structure of thermal rates for a (sub)ohmic bath with an additional factor that guarantees momentum conservation. For a free impurity atom with higher mass than the background atoms it was found [Phys. Rev. A 97, 023621 (2018)] that, due to momentum conservation, thermalization occurs only above a critical momentum. We find similar results for one or many impurity atoms that are additionally subjected to an optical lattice. We show that interesting nonequilibrium steady states can be engineered if the optical lattice is time-periodically driven.

Q 13.4 Mon 16:30 Empore Lichthof

Spinor BEC coupled to an optical cavity: from the Dicke model to spin textures and dissipation induced instabilities — •Nishant Dogra[1,2], Manuele Landini[1,3], Katrin Kroeger[1], Lorenz Hruby[1], Francesco Ferri[1], Rodrigo Rosa-Medina[1], Fabian Finger[1], Tobias Donner[1], and Tilman Esslinger[1] — [1]Institute for Quantum Electronics, ETH Zurich, CH-8093 Zurich, Switzerland — [2]Cavendish Laboratory, University of Cambridge, J. J. Thomson Avenue, Cambridge CB3 0HE, United Kingdom — [3]Institut für Experimentalphysik und Zentrum für Quantenphysik, Universität Innsbruck, 6020 Innsbruck, Austria

In the past decade, the driven-dissipative Dicke model has been realized and extensively studied by coupling a Bose-Einstein condensate (BEC) to an off-resonant laser field and a high-finesse optical cavity. In this poster, I will present our recent experimental results where we have extended this scheme to a spinor BEC allowing us to introduce strong opto-magnetical effects in the system and go beyond the Dicke model. Specifically, by starting with a mixture of two spin states, we identify two qualitatively new regimes. First, a spin texture with spatially modulated magnetization arises as a result of coherent opto-magnetic coupling in the system. Second, the dispersive effect of the resonator losses mediates a dissipative coupling in the system which results in a non-stationary state of chiral nature. Our system provides a model example where both coherent and dissipative regimes are independently realized and furthermore, the transition boundary between the two regimes can be explored.

Q 13.5 Mon 16:30 Empore Lichthof

A New Caesium Quantum Gas Microscope — •Hendrik von Raven[1,2,3], Till Klostermann[1,3], Jingjing Chen[1,3], Christian Schweizer[1,2,3], Cesar Cabrera[1,3], Immanuel Bloch[1,2,3], and Monika Aidelsburger[1,3] — [1]Ludwig-Maximilians Universität München, Schellingstr. 4, 80799 München, Germany — [2]Max Planck Institut für Quantenoptik, Hans-Kopfermann-Str. 1, 85748 Garching, Germany — [3]Munich Center for Quantum Science and Technology, Schellingstr. 4, 80799 München, Germany

Ultra cold atomic systems can be used to investigate topological quantum effects. So far, research has mainly focused on non-interacting systems. We are setting up a new experiment utilizing Caesium that aims to investigate many-body topological quantum effects, such as the fractional quantum hall effect. We build on previous experiments, extending the range of observables to single-site ones using high-resolution objectives and a novel scheme to induce the complex tunneling elements necessary to create topological effects in optical lattices. This novel scheme relies on an anti-magic lattice in which two different hyperfine states of Caesium are trapped in the nodes and anti-nodes of the standing wave potential. Due to a wide Feshbach resonance at low magnetic fields available in Caesium, we will be able to tune the onsite interaction over a broad range. This poster also will give a status report on the progress of the experiment build up so far.

Q 13.6 Mon 16:30 Empore Lichthof

Universal Dynamics in Bose Gases Far from Equilibrium — •Paul Grosse-Bley, Philipp Heinen, Christian-Marcel Schmied, and Thomas Gasenzer — Kirchhoff-Institut für Physik, Ruprecht-Karls-Universität Heidelberg, Im Neuenheimer Feld 227, 69120 Heidelberg, Germany

Far from equilibrium, comparatively little is known about the possibilities nature reserves for the structure and states of quantum many-body systems. Starting from a far-from equilibrium initial configuration a quantum many-body system can approach a non-thermal fixed point exhibiting universal scaling in time and space. Such fixed points have been discussed analytically as well as numerically and have recently been observed in experiments.

Different underlying physical configurations and processes can lead to the universal scaling characterizing the evolution at the fixed point. In particular, the dynamics can either be driven by the reconfiguration and annihilation of (topological) defects populating the system or by conserved redistribution of quasiparticle excitations. We introduce far from equilibrium initial configurations that feature different physical configurations by means of parameter quenches.

In our work we numerically analyze Bose gases in up to three spatial dimensions using the semi-classical truncated Wigner method. We calculate correlation functions in order to extract universal properties of the system. To unravel the underlying physics characterizing the evolution of systems at the non-thermal fixed point we specifically investigate phase correlations and higher order field correlations.

Q 13.7 Mon 16:30 Empore Lichthof

A two-dimensional box trap for bosons with tuneable interactions — •Julian Schmitt, Panagiotis Christodoulou, Maciej Galka, Nishant Dogra, Jay Man, and Zoran Hadzibabic — Cavendish Laboratory, University of Cambridge, UK

Ultracold atoms constitute a powerful platform to study strongly-correlated many-body physics due to the high level of control of their confinement, interactions and dimensionality. While interacting three-dimensional Bose gases exhibit superfluidity induced by Bose-Einstein condensation, two-dimensional Bose gases may become superfluid via the Berezinski-Kosterlitz-Thouless (BKT) mechanism, as observed in e.g. harmonically trapped gases. Probing the nature of the phase transition and the role of interactions, however, has been hampered by the inhomogeneous density distributions of these samples. In this poster, I will present our experimental implementation of a uniform two-dimensional superfluid Bose gas in an optical box trap, which provides access to the thermodynamics and genuine out-of-equilibrium dynamics over the entire system size. The two-dimensional confinement of the gas is realised by repulsive light sheets that allow to dynamically change the trap frequency using a digital micromirror device (DMD). Similarly, the in-plane variable box potential is derived from another DMD acting as an amplitude mask. Finally, our ^{39}K sample allows us to also vary the atomic interactions by employing a magnetic Feshbach resonance. Using the highly tuneable platform, we determine the thermodynamic equation of state of the gas and investigate the elementary excitations by driving the system out of equilibrium.

Q 13.8 Mon 16:30 Empore Lichthof

Dynamical variational approach to Bose polarons at finite temperatures — •David Dzsotjan[1], Richard Schmidt[2], and Michael Fleischhauer[1] — [1]TU Kaiserslautern, Kaiserslautern, Germany — [2]Max-Planck-Institute of Quantum Optics, Garching, Germany

Polarons appear as the result of interaction between a large number of majority particles and a few impurities. Here, we discuss the interaction of a mobile quantum impurity with a Bose-Einstein condensate of atoms at finite temperature. To describe the resulting Bose polaron formation we apply a dynamical variational approach to an initial thermal gas of Bogoliubov phonons. We study the polaron formation after switching on the interaction, e.g., by a radio-frequency (RF) pulse from a non-interacting to an interacting state (injection spectrum). We calculate the real-time impurity Green's function and discuss its temperature dependence. Furthermore, we determine the RF absorption spectrum and find good agreement with recent experimental observations. We predict temperature-induced shifts and a substantial broadening of spectral lines. The analysis of the real-time Green's function reveals a crossover to a linear temperature dependence of the thermal decay rate of Bose polarons as the unitary interaction regime is approached. We also show the results of our work concerning the polaronic ejection spectrum, i.e., when from a steady-state polaron one transfers the impurity to a state where it no longer interacts with the majority bosons.

Q 13.9 Mon 16:30 Empore Lichthof

Quantum State Tomography of Ultracold Atoms in Optical Superlattices via Machine Learning — •Guo-Xian Su[1,2], Zhen-Sheng Yuan[1,2], and Jian-Wei Pan[1,2] — [1]Physikalisches Institut, Ruprecht-Karls-Universitat Heidelberg, Im Neuenheimer Feld 226, 69120 Heidelberg, Germany — [2]Hefei National Laboratory for Physical Sciences at Microscale and Department of Modern Physics, University of Science and Technology of China, Hefei, Anhui 230026, China

Optical superlattices enabled preparation of quantum many-body states with ultracold atoms, however, traditional methods of detection and reconstruction of these states requires exponential amount of computational resources. Following recent development of machine learning technics, we demonstrate the use of restricted Boltzmann machine to reconstruct complex quantum states up to 10 Qu-bits prepared with $\sqrt{SWAP}$ operation in superlattices with less than 1000 measurements, which is impossible with brutal-force tomography. This method can be useful for large-scale quantum simulation with ultracold atoms.

Q 13.10 Mon 16:30 Empore Lichthof

Probing entanglement in many-body systems — •Julian Léonard, Robert Schittko, Sooshin Kim, Joyce Kwan, and Markus Greiner — Harvard University, Cambridge, MA, USA

Entanglement is one of the most intriguing features of quantum mechanics. It describes non-local correlations between quantum objects, and it is at the heart of quantum information sciences. In a many-body system, the entanglement can reveal key properties of the underlying physics, which are elusive to other observables.

Here, we elucidate the entanglement properties in different pure quantum states far from equilibrium by measuring a number of entanglement quantities. Firstly, we study the dynamics in a Luttinger liquid after a quantum quench. We observe the formation of bipartite entanglement through the spreading of quasi-particles, which give access to the system's Luttinger parameter. Secondly, we prepare a strongly disordered Bose-Hubbard system far from equilibrium. We identify the emergence of many-body localization by the logarithmically slow formation of entanglement in the system. Finally, we study the weakly disordered Bose-Hubbard system, and identify a spatially separated, sparse-resonant structure, which persists into non-factorizable higher-order correlations.

Q 13.11 Mon 16:30 Empore Lichthof

Critical properties of the extended Bose-Hubbard model with global interactions — Shraddha Sharma[1], •Rebecca Kraus[2], Simon B. Jager[2], Tommaso Roscilde[3,4], and Giovanna Morigi[2] — [1]The Abdus Salam International Center for Theoretical Physics, Strada Costiera 11, 34151 Trieste, Italy — [2]Theoretische Physik, Universität des Saarlandes, D-66123 Saarbrücken, Germany — [3]Laboratoire de Physique, CNRS UMR 5672, Ecole Normale Supérieure de Lyon, Université de Lyon, Ens de Lyon, Université Claude Bernard, CNRS, Laboratoire de Physique, F-69342 Lyon, France — [4]Institut Universitaire de France, 103 boulevard Saint-Michel, F-75005 Paris, France

We consider a bosonic gas in a two-dimensional optical lattice. The atoms interact via s-wave scattering and via the global interactions induced by the coupling with a cavity. The phase diagram here is characterized by a Mott-insulator (MI), superfluid (SF), charge-density (CDW) wave, and supersolid (SS) phase, which emerge from the interplay between kinetic energy, contact interaction, and global interactions. We determine the entanglement entropy and entanglement spectrum across the phase diagram by means of a controlled perturbative expansion above the mean-field ground state. We relate their behavior to the physical excitation spectrum and discuss the nature of the phase transitions.

Q 13.12 Mon 16:30 Empore Lichthof

Light-matter interactions in cold dysprosium atoms — •Marcel Trümper[1], Niels Petersen[1,2], and Patrick Windpassinger[1,2] — [1]QUANTUM, Institut für Physik, Johannes Gutenberg-Universität Mainz, Staudingerweg 7, 55128 Mainz, Germany — [2]Graduate School Materials Science in Mainz, Staudingerweg 9, 55128 Mainz, Germany

The fundamental understanding of light-matter interactions and associated phenomena is one of the central endeavors in quantum optics. Extensive research has been performed on a plethora of different systems, including cold and ultra-cold atomic ensembles covering nearly all elements from the periodic table. We are interested in the experimental study of light-matter interactions in dense dipolar media from atoms with large magnetic moments. Dysprosium is the perfect choice for these experiments, since it is the most magnetic element with a magnetic dipole moment of 10 Bohr-magneton.

With this poster we report on recent activities and future work in our laboratory. First, we present results from spectroscopic studies of the 1001 nm ground state transition in dysprosium [arXiv:1907.05754], where we determined the lifetime and polarization of the excited state and measured the isotope shifts of three bosonic isotopes. Further, we give a perspective on our work towards studies of light-propagation effects in dense samples from cold dysprosium atoms. To this end, we report on a microscopic optical dipole trap, which will enable us to achieve the desired densities for our experiments.

Q 13.13 Mon 16:30 Empore Lichthof

Quantifying Entanglement in Bose-Einstein-Condensates using Entropic Uncertainty Relations — •Bjarne Bergh and Martin Gärttner — Kirchhoff-Institut für Physik, Universität Heidelberg, Germany

Entanglement is a key property of quantum mechanical systems and an elementary building block in many quantum mechanical applications. Bose-Einstein-Condensates form interesting systems to study nonlocal entanglement as they allow for precise control of quantum mechanical correlations between many thousand particles and on macroscopic length scales.

Entanglement between two spatially separated subsystems of a Bose-Einstein-Condensate has recently been demonstrated via EPR-Steering. However, this does not allow for a quantitative estimate of the entanglement present in the system. The main difficulty here arises from being very limited in the set of experimentally available observables.

We demonstrate how entropic uncertainty relations, applied to the correlations between two subsystems when measured in multiple sets of bases, can be used to gain bounds on the entanglement entropy. Besides being another entanglement witness, this also provides a bound on the quality of the entangled state.

Q 13.14 Mon 16:30 Empore Lichthof

Partial Distinguishability and Coherence in Many-Body Systems — •Eric Brunner, Christoph Dittel, Gabriel Dufour, and Andreas Buchleitner — Quantenoptik und -statistik, Physikalisches Institut, Albert-Ludwigs-Universität Freiburg

Many-body interference in the dynamics of identical particles is controlled by their mutual indistinguishability. This can be tuned by addressing suitable "label" degrees of freedom. Through a systematic analysis of coherence in the dynamical modes, limited by entanglement between dynamical and label degrees of freedom, we define a hierarchy of indistinguishability measures. Identifying robust signatures of many-body interference in randomized correlation measurements allows us to uncover the coherence structure of a given input state, and, therefore, to assess the degree of indistinguishability. This paves the way for an experimental quantification of partial distinguishability in general non-interacting many-body systems.

Q 13.15 Mon 16:30 Empore Lichthof

Detecting Bell correlations in a Bose-Einstein condensate — •Adrian Braemer and Martin Gärttner — Kirchhoff-Institut für Physik, Heidelberg

Bell correlations are the strongest type of quantum correlations and serve as a resource in many quantum information processes. They are detected through violations of Bell's inequalities, such as the CHSH inequality. This has been shown in many experiments typically using discrete-valued observables. For continuous variable systems violation has been achieved using squeezed states of light. However, highly entangled states have also been demonstrated with ultracold atoms. Motivated by this we propose a scheme to detect Bell correlations in a spinor BEC allowing a Bell test on a mesoscopic ensemble of massive particles.

Q 13.16 Mon 16:30 Empore Lichthof

Dynamics of entanglement creation between two spins coupled to a chain — •Christian Otto[1], Pierre Wendenbaum[1,2], Bruno G. Taketani[3], Endre Kajari[1], Giovanna Morigi[1], and Dragi Karevski[2] — [1]Universität des Saarlandes — [2]Universite de Lorraine — [3]Universidade Federal de Santa Catarina

We study the dynamics of entanglement between two spins which is created by the coupling to a common thermal reservoir. The reservoir is a spin-1/2 Ising transverse field chain thermally excited, the two defect spins couple to two spins of the chain which can be at a macroscopic distance. In the weak-coupling and low-temperature limit the spin chain is mapped onto a bath of linearly interacting oscillators using the Holstein-Primakoff transformation. We analyse the time evolution of the density matrix of the two defect spins for transient times and deduce the entanglement which is generated by the common reservoir. We discuss several scenarios for different initial states of the two spins and for varying distances.

Q 13.17 Mon 16:30 Empore Lichthof

Optical Dipole Trap as a Source of Ultracold Atoms in Microgravity — •Marian Woltmann[1], Christian Vogt[1], Sven Herrmann[1], Claus Lämmerzahl[1], and The PRIMUS-Team[1,2] — [1]University of Bremen, Center of Applied Space Technology and Microgravity (ZARM) — [2]LU Hannover, Institute of Quantum Optics

Cold atoms have proven to be effective tools with wide applications in measuring weakest forces and thereby in testing fundamental physics e.g. the weak equivalence principle. The sensitivity of such atom interferometer measurements scales with the square of the interrogation time, typically limited by the size of the vacuum chamber. Therefor the step to employ atom interferometers in weightlessness offers the potential of highly increased sensitivities. While most microgravity cold atom experiments use magnetic trapping with an atom chip, the PRIMUS-project develops an optical dipole trap as an alternative source of ultracold atoms in a drop tower experiment. As the dipole trap is based on optical interactions only, Feshbach resonances will become feasible in microgravity. Furthermore the optical dipole trap allows to trap all magnetic sub-states and offers an enhanced symmetry of the trapping potential. This poster will give an overview of the experiment and report on latest results. The PRIMUS-project is supported by the German Space Agency DLR with funds provided by the Federal Ministry for Economic Affairs and Energy (BMWi) under grant number DLR 50 WM 1642.

Q 13.18 Mon 16:30 Empore Lichthof

A high-flux source of rubidium Bose-Einstein condensates for atom interferometry — •Dorothee Tell, Christian Meiners, Henning Albers, Dennis Schlippert, and Ernst M. Rasel — Leibniz Universität Hannover, Institut für Quantenoptik, Germany

Using Bose-Einstein condensates (BEC) for atom interferometry enables increased sensitivity for inertial measurements. A large number of atoms in the interferometer lowers the shot-noise of the readout, while a high repetition rate - usually limited by the duration of BEC creation - is needed for fast averaging and increased temporal resolution. Therefore we aim for a fast source producing a high number of atoms in a quantum-degenerate state.

We present the implementation of a rubidium source which uses a sequence of a dual MOT system loading $5 \cdot 10^9$ atoms in 200 ms and a high power crossed optical dipole trap to create BECs. Dynamically shaped potentials are used to optimize the speed and efficiency of evaporative cooling towards unprecedented BEC flux. Finally, we evaluate the impact of this source on experiments in a 10 m baseline in the Hannover Very Long Baseline Atom Interferometry facility (VLBAI).

This work is funded by the DFG as a major research equipment (VLBAI facility), via the CRCs 1128 "geo-Q" and 1227 "DQ-mat", under Germany's Excellence Strategy (EXC 2123) "QuantumFrontiers", and by the Federal Ministry of Education and Research (BMBF) through the funding program Photonics Research Germany (contract number 13N14875).

Q 13.19 Mon 16:30 Empore Lichthof

Performance of a CMOS based atom chip — Felix Wenzl[1], David Werban[1], Philipp Neumann[1], Alexander Nemecek[1], Thomas Fernholz[2], Mark Fromhold[2], and •Christian Koller[1] — [1]Fachhochschule Wiener Neustadt, Johannes Gutenbergstraße 3, 2700 Wiener Neustadt, Austria — [2]School of Physics and Astronomy, The University of Nottingham, University Park Nottingham, NG7 2RD, UK

Neutral atoms and atom chip technology have proven to be an excellent toolkit for the realisation of experiments in fundamental science such as atom interferometry or the study of one-dimensional systems. Ongoing efforts are currently developing them into versatile platforms for quantum-based sensors for e.g. gravity or magnetic fields. As atom chips are based on the tools of modern semiconductor fabrication, they provide a pathway to the very large-scale integration of quantum devices. Nevertheless, current state-of the-art atom chips are usually fabricated as prototypes in research facilities, not using the vast capabilities of modern, commercial semiconductor foundries, resulting in high costs and low throughput of these devices. In this work we will present test results for a next generation atom chip fully build in a commercial foundry utilizing 0.35 μm Complementary Metal Oxide Semiconductor (CMOS) technology. We will show that this chip can reach specification comparable to state-of-the art atom chips but extends the standard capabilities due to the integration of multilayer structures, on-board current switching capabilities, reconfigurable magnetic traps, integrated photodetection and read-out electronics.

Q 13.20 Mon 16:30 Empore Lichthof

Controlling multipole moments of a magnetic chip trap — •Tobias Liebmann and Reinhold Walser — Institut für Angewandte Physik, Technische Universität Darmstadt, Hochschulstr. 4a, 64289 Darmstadt

Magnetic chip traps are a standard tool for trapping atoms [1,2]. These are robust devices with multiple fields of use ranging from fundamental physics experiments [3] to applications of inertial sensing [2]. While magnetic traps do provide good confinement potentials, they are not necessarily harmonic, in particular they can exhibit strong cubic anharmonicity. In this contribution, we will discuss methods of designing printable 2D wire guides, which compensate unfavorable multipole moments. A theoretical approach is proposed to reduce the unwanted multipole moments of a Z-chip trap by introducing a small disturbance to the standard wire configuration. Using a suitable representation of the disturbance, the resulting magnetic field is calculated via the Biot-Savart law. This allows one to calculate the multipole moments in proximity to the trap minimum, as a result the rogue multipole moments can be minimized.

[1] J. Reichel, and V. Vuletic, eds. *Atom chips.* John Wiley & Sons, 2011.
[2] M. Keil, et al. "Fifteen years of cold matter on the atom chip: promise, realizations, and prospects." *Journal of Modern Optics* 63, 1840 (2016).
[3] D. Becker, et al. "Space-borne Bose-Einstein condensation for pre-

cision interferometry." *Nature* 562, 391 (2018).

Q 13.21 Mon 16:30 Empore Lichthof

Improved Laser System for Optical Trapping of Neutral Mercury — •Rudolf Homm, Daniel Preissler, and Thomas Walther — Technische Universität Darmstadt, Institut für Angewandte Physik, Laser und Quantenoptik, Schlossgartenstraße 7, 64289 Darmstadt

Cold Hg-atoms in a magneto-optical trap offer opportunities for various experiments. The two stable fermionic isotopes are interesting with regard to a new time standard based on an optical lattice clock employing the $^1S_0$ - $^3P_0$ transition at 265.6 nm. The five stable bosonic isotopes can be used to form ultra cold Hg-dimers through photo-association in connection with vibrational cooling by applying a specific excitation scheme.

The laser system consists of an ECDL at 1014.8 nm followed by a Yb-fiber amplifier and two consecutive frequency-doubling stages. Due to a 50W-pumplaser at 976 nm the power of the ECDL was amplified to about 12 W. This results in about 5 W at 507.4 nm after the first frequency-doubling cavity.

The limiting factor in generating high power at 253.7 nm so far, was the degradation of the non-linear BBO-crystal used in the second frequency-doubling stage. To avoid this problem, we developed a cavity with elliptical focusing [1], which was already successfully tested in other laser systems [2]. Our goal is to replace the actual cavity with one with elliptical focusing to reach higher power at 253.7 nm without degradation. We will report on the status of the experiments.

[1] Preißler, D., *et al.*, *Applied Physics B* **125** (2019): 220

[2] Kiefer, D., *et al.*, *Laser Physics Letters* **16** (2019): 075403

Q 13.22 Mon 16:30 Empore Lichthof

Elementary laser-less quantum logic operations with antiprotons in Penning traps — •Diana Nitzschke[1], Marius Schulte[1], Malte Niemann[2], Juan Cornejo[2], Ralf Lehnert[3], Christian Ospelkaus[2], and Klemens Hammerer[1] — [1]Institute for Theoretical Physics and Institute for Gravitational Physics (Albert-Einstein-Institute),Leibniz University Hannover, Appelstrasse 2, 30167 Hannover, Germany — [2]Institute of Quantum Optics, Leibniz Universität Hannover, Welfengarten 1, 30167 Hannover, Germany — [3]Indiana University

Static magnetic feld gradients superimposed on the electromagnetic trapping potential of a Penning trap can be used to implement laserless spin-motion couplings that allow the realization of elementary quantum logic operations in this system. An important scenario of practical interest is the application to g-factor measurements with single (anti-)protons to test CPT invariance. We discuss the classical and quantum behavior of a charged particle in a Penning trap with a superim- posed magnetic feld gradient. Using analytic and numeric calculations, we find that it is possible to carry out a SWAP gate between the spin and the motional qubit of a single (anti-)proton with high fidelity, provided the particle has been initialized in the motional ground state. We discuss the implications of our findings for the realization of quantum logic spectroscopy in this system.

Q 13.23 Mon 16:30 Empore Lichthof

Semiclassical Laser Cooling in a Strongly Focussed Laser Field — •Maximilian Schumacher, Thorsten Haase, and Gernot Alber — Institut für Angewandte Physik, Technische Universität Darmstadt, Hochschulstraße 4a, D-64289 Darmstadt

The semiclassical theory of laser cooling above the Doppler limit describes many experiments in quantum optics and quantum information science. In this contribution this semiclassical laser theory is applied to describe a scenario in which a (classical) laser field is strongly focused. Our investigation is motivated by the 4PiPac experiment [1] performed in Erlangen in which a single ion is trapped in the focus of a parabolic mirror and is driven almost resonantly by a laser field entering this cavity as a plane wave. Modelling this ion by a degenerate multi-level system the influence of the strongly focused laser beam and its peculiar polarization properties on the center-of-mass motion of the ion are explored. Comparison of these results with the corresponding results of a two-level model for the ion exhibit the characteristic effects caused by this peculiar polarization dependence of the laser field.

[1] Alber L., Fischer M., Bader M., Mantel K., Sondermann M., Leuchs G., J. Europ. Opt. Soc. Rap. Public. 13, 14 (2017)

Q 13.24 Mon 16:30 Empore Lichthof

Highly dynamical microwave source with low phase noise for cold atom experiments — •Bernd Meyer, Alexander Idel, Fabian Anders, and Carsten Klempt — Institut für Quantenoptik, Leibniz Universität Hannover

Entangled states in Bose-Einstein condensates (BECs) can be employed for precision metrology and for exploring fundamental physics. The generation of entanglement can be achieved by spin-changing collisions in a spinor Bose-Einstein condensate. This process allows for the creation of pair correlations and full many-particle entanglement within the atomic ensemble. [1]

The preparation of the initial states and the manipulation of the entangled states require the application of tailored microwave fields. The fidelity of the created states is often limited by microwave phase noise. In an atom interferometer, this noise generally deteriorates the interferometric signal. Reduction of the microwave's phase noise is thus crucial for high-precision measurements at the shot noise level.

We will present a novel microwave source based on FPGA-controlled Direct Digital Synthesis (DDS). The source offers adjustable frequency, phase and amplitude with update times of only 700 ns. When using RAM of the DDS, shaped pulses with different parameters can be applied. The resulting phase noise is in the range of -125 dBc/Hz to -130 dBc/Hz for offset frequencies of 20 kHz to 20 MHz.

[1] B. Lücke *et al.*, *Phys. Rev. Lett.*, **112**, 155304 (2014).

Q 13.25 Mon 16:30 Empore Lichthof

A high-flux Yb source for atom interferometry using a core-shell MOT — •Robert J. Rengelink, Etienne Wodey, Dennis Schlippert, and Ernst M. Rasel — Leibniz Universität Hannover, Institut für Quantenoptik, Germany

In high-performance atom interferometry the short term stability is ultimately limited by shot-noise and the repetition rate of the experiment. In order enable new geophysical and fundamental science applications of Very Long Baseline Atom Interferometry (VLBAI) it is therefore necessary to develop high-flux sources.

We present a high-flux ytterbium source that can be subdivided into two parts. The first consists of an oven with a microtube array nozzle, a Zeeman slower based on a Hallbach array of permanent magnets, and a 2D-MOT deflection/collimation stage. This produces a cold flux in excess of 10^9 atoms/s into the MOT chamber.

The second part is a two-colour MOT in a so-called core-shell configuration: A hollow beam tuned to the strong $^1S_0 \rightarrow ^1P_1$ transition at 399 nm is applied to capture as much flux as possible and transfers the atoms to a central MOT at the narrow $^1S_0 \rightarrow ^3P_1$ transition at 556 nm which cools them to low temperatures and traps with a long lifetime. Finally, we compare and contrast the core-shell MOT with a sequential two-colour MOT. The VLBAI facility is a major research equipment funded by the DFG. We acknowledge support from the CRCs 1128 “GeoQ” and 1227 “DQ-mat”, the Cluster of Excellence 2123 “QuantumFrontiers”, and by BMBF (13N14875)

Q 13.26 Mon 16:30 Empore Lichthof

Influence of silicon dioxide layer on losses and switching behaviour of electro-optical modulators in $LiNbO_3$ — •Silia Babel, Felix vom Bruch, Christof Eigner, and Christine Silberhorn — Universität Paderborn, Warburger Str. 100, 33098 Paderborn

The transmission and encoding of information via glass fibers and electro-optical modulation is a well established technology.
Lately, quantum communication becomes more and more important. In order to be able to use classical modulators for quantum communication, these must be optimized according to novel system specifications. The optical losses caused by using the modulators have to be reduced, since qubits, in which the information is encoded, cannot be classically amplified. Furthermore, feed-forward schemes are essential ingredients for quantum communication, but due to their complexity not yet entirely released. To overcome this obstacle, the interplay and functionality between the different components has to be optimized and here, we concentrate on the switching behaviour of the required electro-optical modulators. The platform of choice is lithium niobate waveguide structures. They offer potentially low losses in combination with significantly faster switching behaviour compared to bulk modulators. This can be achieved by a smaller electrode gap, which allows lower switching voltages resulting in a decrease of the switching time. The optical losses as well as the switching behaviour depend on the design of the electrodes. Therefore, in order to achieve faster and lower-loss electro-optical modulators, the losses caused by the electrodes and the switching are examined as a function of the buffer layer.

Q 13.27 Mon 16:30 Empore Lichthof

Self-Induced Transparency in Room-Temperature Dense Ry-

dberg Gases — •Zhengyang Bai[1,2], Weibin Li[1], and Guoxiang Huang[2] — [1]School of Physics and Astronomy, and Centre for the Mathematics and Theoretical Physics of Quantum Non-equilibrium Systems, University of Nottingham, Nottingham, NG7 2RD, UK — [2]State Key Laboratory of Precision Spectroscopy, East China Normal University, Shanghai 200062, China

Aggressively large Doppler effects is of the challenge to create static optical nonlinearities in atomic gases beyond ultracold temperatures. We show the creation of strong dispersive optical nonlinearities of nanosecond laser pulses in high number density atomic gases at room temperature. This is examined in a vapor cell setting where the laser light resonantly excites atoms to Rydberg P states through a single-photon transition. Using fast Rabi flopping and strong Rydberg atom interactions, both in the order of GHz, can overcome the Doppler effect as well as dephasing due to thermal collisions between Rydberg electrons and surrounding atoms. In this strong-driving regime both the light intensity and Rydberg interactions contribute to the generation of the optical nonlinearity. We show the emergence of a modified self-induced transparency (SIT) where the stable light propagation relies on the Rydberg interactions. We identify quantitatively that the SIT occurs at smaller (than 2π) pulse areas for higher Rydberg states. We furthermore demonstrate that a conditional optical phase gate can be implemented by harvesting strong Rydberg atom interactions and SIT.

Q 13.28 Mon 16:30 Empore Lichthof

Simulating storage of quantum dot photons in an atom-cavity system — •Maximilian Ammenwerth, Lukas Ahlheit, Wolfgang Alt, Tobias Macha, Pooja Malik, Deepak Pandey, Hannes Pfeifer, Eduardo Uruñuela, and Dieter Meschede — Institut für Angewandte Physik der Universität Bonn Wegelerstr. 8, 53115, Bonn, Germany

Large-scale quantum networks based on the synchronized transfer of single photons require efficient light-matter interfaces which can generate and store photons deterministically. In this regard, the small mode volume of fiber-based Fabry-Pérot cavities offers strong light-matter coupling with high-bandwidth. In our experiment a single rubidium atom is coupled to the cavity. Using a cavity-assisted Raman process we recently demonstrated the storage of short light pulses in such a coupled atom-cavity system [1]. The successful storage of a weak coherent wave packet with a full width at half maximum of 5 ns encourages hybrid experiments with semiconductor quantum dots as a single photon source.

We numerically compute the expected storage efficiency for weak coherent and single photon pulses by means of a numerical simulation that takes into account our system parameters as well as a typical pulse shape of quantum dot photons. The optimal control pulse is found from a numerical optimisation based on simulating the system dynamics via the Lindblad master equation.

[1] T. Macha, et al., arXiv:1903.10922v2 (2019)

Q 13.29 Mon 16:30 Empore Lichthof

Designing high precision electronics for an atom interferometer on the ISS — •Alexandros Papakonstantinou[1], Thijs Wendrich[1], Wolfgang Bartosch[1], Christian Schubert[1], Ernst M. Rasel[1], Wolfgang Ertmer[1], and the BECCAL Team[1,2,3,4,5,6,7] — [1]Institut für Quantenoptik, Leibniz Universität Hannover — [2]Institut für Mikroelektrische Systeme, Leibniz Universität Hannover — [3]Universität Ulm — [4]Ferdinand Braun Institut — [5]Humboldt Universität Berlin — [6]Johannes Gutenberg Universität Mainz — [7]ZARM Universität Bremen

The Einstein equivalence principle has been tested with in dual species atom interferometers. Compared to ground based experiments, the ISS provides a microgravity environment and can therefore increase the free fall time in ground based experiments. For running such an atom interferometer in a space born platform, high precision and compact electronics are needed. Strict requirements for the operation on the ISS such as operation safety and size demand new developments for several electronic components. Based on our experience from other space missions such as the MAIUS 2/3 sounding rocket missions, the new components will be designed to comply with these specific restrictions. In this poster we show the overall design of the electronics and the progress in our work. This project is supported by the German Space Agency DLR with funds provided by the Federal Ministry for economic affairs and energy (BMWi) under the grant numbers 50WP1431 and 50WP1700.

Q 13.30 Mon 16:30 Empore Lichthof

Compact, miniaturized and robust electronics for the operation of a dual species atom interferometer on a sounding rocket — •Wolfgang Bartosch, Thijs Wendrich, Alexandros Papakonstantinou, Matthias Koch, Maike Lachmann, Baptist Piest, Wolfgang Ertmer, Ernst Maria Rasel, and the MAIUS-Team — Institut für Quantenoptik, Leibniz Universität Hannover

Quantum sensors based on atom interferometry have become a valuable tool in numerous fields of scientific research. The sensitivity of atom interferometers depends predominantly on the possible free falling time of the coherently split atomic ensemble. Hence working towards a space born experiment, where the free falling time is only limited by the expansion rate of the atomic ensemble, is a logical step. The MAIUS-2/3 sounding rocket missions will be a step towards such a space born experiment by showing the feasibility of a dual species atom interferometer in space. Based on our experience from the predecessor mission MAIUS-1, we improved our electronics to match the needs of a mission with two species. We downsized the electronic components used for MAIUS-1 to fit hardware for dual species operation in an apparatus of the same size. With this poster we present our current progress. The QUANTUS/MAIUS project is supported by the German Space Agency DLR with funds provided by the Federal Ministry of Economics and Technology (BMWi) under grant number: 50WP1431

Q 13.31 Mon 16:30 Empore Lichthof

Waveguide integrated superconducting nanowire single-photon detectors made from NbTiN thin films — •Martin A. Wolff[1,2,3,4], Simon Vogel[1,2,3], Matthias Häussler[1,2,3], Lukas Splitthoff[1,2,3], and Carsten Schuck[1,2,3] — [1]Physics Institute, University of Münster, Wilhelm-Klemm-Str. 10, 48149 Münster, Germany — [2]CeNTech - Center for NanoTechnology, Heisenbergstr. 11, 48149 Münster, Germany — [3]SoN - Center for Soft Nanoscience, Busso-Peus-Str. 10, 48149 Münster, Germany — [4]martin.wolff@wwu.de

Superconducting nanowire single-photon detectors (SNSPDs) are an ideal match for integrated quantum photonic circuits because efficient interfaces between waveguide and detector are straightforwardly achieved. Employing a traveling wave geometry allows for simultaneously realizing high detection efficiency, low noise and accurate timing in high-speed operation [1]. Here we show that these performance characteristics are achievable across several photonic integrated circuit platforms using a universal fabrication process. We fabricate SNSPDs on Si3N4, Ta2O5 and LiNbO3 using a room-temperature magnetron sputtering process for niobium titanium nitride (NbTiN) thin films and state-of-art nanofabrication methods. Our process yields detectors with $> 80\%$ efficiency, MHz count rates, < 30 ps jitter and milli-Hz dark count rates at the telecommunication wavelength of 1550 nm. Our work opens up the possibility for retrofitting nanophotonic chips with single-photon detectors across a wide range of dielectric material systems. [1] S. Ferrari et al., Nanophotonics, 7, 1725 (2018)

Q 13.32 Mon 16:30 Empore Lichthof

Towards a setup for HBT measurements using small telescopes — •Sebastian Karl[1], Stefan Richter[1,2], and Joachim von Zanthier[1,2] — [1]Institut für Optik, Information und Photonik, Universität Erlangen-Nürnberg, 91058 Erlangen, Germany — [2]Erlangen Graduate School in Advanced Optical Technologies (SAOT), Universität Erlangen-Nürnberg, 91052 Erlangen, Germany

The ability to measure temporal intensity correlation functions with high SNR and predictable contrast can be regarded as the first step towards spatial Hanbury Brown Twiss (HBT) intensity interferometry [1]. Recently such measurements have been performed using the light of arc lamps [2] and of real stars using large optical [3, 4] and Cherenkov [5] telescopes. We present a setup and laboratory test results of temporal intensity correlation measurements with sub 100 ps resolution using a Xenon arc lamp. Our measurement results fit our theory and simulations [6] extremely well. In the light of recent HBT revival experiments [3, 4, 5] we discuss a setup to measure temporal intensity correlations utilizing small telescopes of 0.5 m diameter and high timing resolution.

[1] R. Hanbury Brown, R. Q. Twiss, Nature 177, 27 (1956). [2] P. K. Tan et al., Astrophysical JL 789, L10 (2014). [3] W. Guerin et al., MNRAS 472, 4126 (2017). [4] W. Guerin et al., MNRAS 480, 245 (2018) [5] N. Matthews et al., arXiv 1908.03587 (2019) [6] R. Schneider et al., Appl. Opt. 57, 7076 (2018).

Q 13.33 Mon 16:30 Empore Lichthof

Fast Photon Storage in an Atom-Cavity System with Raman Cooling — •Lukas Ahlheit, Wolfgang Alt, Maximilian Ammenwerth, Tobias Macha, Pooja Malik, Deepak Pandey, Hannes Pfeifer, Eduardo Uruñuela, and Dieter Meschede — Institute for Applied Physics, Bonn, Germany

Atoms coupled to a high bandwidth fiber-cavity are a promising platform for storing temporally short photons, a versatile information carrier in quantum networks.

In our system the atoms are trapped in a 3D-lattice at the center of the fiber cavity and pre-cooled with a degenerate raman sideband cooling technique [1]. Then carrier-free Raman cooling is used to prepare them close to the 3D motional ground state using the intra-cavity blue detuned dipole trap and a DBR laser. In order to phase lock the DBR to the dipole trap laser, the linewidth of the DBR laser is reduced by optical feedback through a meter-long external cavity to a few tens of kHz.

Photon storage is accomplished with the D2 line of ^{87}Rb through a cavity-assisted two photon Raman process in Λ-configuration. This promises photon generation and storage in a controlled and deterministic way with improved efficiencies compared to our previous work [2]. The simulation for the expected storage efficiency along with the experimental findings are presented.

[1] E. Uruñuela, et al., arXiv:1909.08894 (2019)
[2] T. Macha, et al., arXiv:1903.10922 (2019)

Q 13.34 Mon 16:30 Empore Lichthof

Directly Laser-Written Lab-on-Tip for Nanoscale Sensing — •José Ferreira Neto[1], Jonas Gutsche[1,2], Ashkan Zand[1], Stefan Dix[1], Stefan Guckenbiehl[1], and Artur Widera[1,2] — [1]Physics Department and State Research Center OPTIMAS, University of Kaiserslautern, 67663 Kaiserslautern, Germany — [2]Graduate School Materials Science in Mainz, Erwin-Schrödinger-Str. Gebäude 46, 67663 Kaiserslautern, Germany

Nitrogen-vacancy (NV) centers in diamond have advanced to a highly promising nano-scale probe. A prominent feature of the NV center is optical initialization and readout of its spin degree of freedom, which can also be controlled via microwave fields. Due to low cytotoxicity, relatively long coherence times at room temperature, and its high sensitivity to external fields, it is widely used to detect DC and AC magnetic fields and to sense temperature distributions in biological samples.

We present the incorporation of nanodiamonds containing NV centers into direct-laser-written (DLW) three-dimensional polymer photonic structures on a fiber tip. In addition, we show our approach to integrate a microwave antenna for NV spin control manufactured with metal DLW to the same fiber tip and complement our studies with simulations performed in COMSOL. This paves the way to a fully integrated "Lab-on-Tip" for biological applications.

Q 13.35 Mon 16:30 Empore Lichthof

Incoherent Diffraction Imaging - Utilizing Intensity Interferometry for Imaging with Hard X-Rays — •Stefan Richter[1,2], Fabian Trost[3], Anton Classsen[1,2], Kartik Ayyer[2], Henry Chapman[3,4,5], Ralf Röhlsberger[5,6], and Joachim von Zanthier[1,2] — [1]Universität Erlangen-Nürnberg, Erlangen — [2]Erlangen Graduate School in Advanced Optical Technologies (SAOT), Universität Erlangen-Nürnberg, Erlangen — [3]Center for Free-Electron Laser Science, DESY, Hamburg — [4]Universität Hamburg, Hamburg — [5]The Hamburg Centre for Ultrafast Imaging, Hamburg — [6]DESY, Hamburg

Intensity correlations were initially used in astronomy for determining the diameter or the separations of stars [1]. Recently, it was shown that this technique can also be employed in the x-ray domain to reveal the arrangement of atoms in crystals or molecules that scatter incoherent x-ray fluorescence photons [2]. Correlating incoherent fluorescence photons, a larger volume of the Fourier space is accessible and elements specific imaging is possible [2]. Here we present numerical simulations of this technique, including correlating photons in 3D Fourier space, rotation of microcrystals when jetted in a beam and normalization of the correlations. We also discuss the influence of different sources of noise.

[1] R. Hanbury Brown, J. Davis, L. R. Allen, Mon. Not. R. astr. Soc. 167, 121 (1974) [2] A. Classen, K. Ayyer, H. N. Chapman, R. Röhlsberger, J. von Zanthier, Phys. Rev. Lett. 119, 053401 (2017).

Q 13.36 Mon 16:30 Empore Lichthof

Mueller matrix microscopy setup for nanoform metrology — •Jana Grundmann, Tim Käseberg, and Bernd Bodermann — Physikalisch-Technische Bundesanstalt, Bundesallee 100, 38116 Braunschweig, Germany

Mueller matrix ellipsometry is an indirect method for measuring optical parameters of a nanostructure. As an extension, the classical Mueller matrix ellipsometer can be combined with a microscope to a Mueller matrix microscope, which can measure Mueller matrices pixel by pixel. We constructed a microscope of this kind in such a way that measurements can be made both in reflection and transmission. Our device is a so called dual-rotating compensator ellipsometer and has a CCD-camera as a detector. In a first step, the light source will be a white LED in combination with different passband filters for monochromatic measurements. It is planned to extend the set-up later with a monochromator and a 1 kW xenon lamp to enable spectroscopic measurements. This system will be used to investigate the capability of imaging Mueller ellipsometry to provide additional information on the shape of nano-scaled structures which cannot be seen in classical bright field microscope images. This is done in particular by analyzing the off-diagonal Mueller matrix elements.

Q 13.37 Mon 16:30 Empore Lichthof

Mechanically decoupling of Quantum Emitters in Hexagonal Boron Nitride — •Felix A. Breuning[1], Michael Hoese[1], Prithvi Reddy[2], Andreas Dietrich[1], Michael K. Koch[1], Konstantin G. Fehler[1,3], Marcus W. Doherty[2], and Alexander Kubanek[1,3] — [1]Institute for Quantum Optics, Ulm University, D-89081 Ulm, Germany — [2]Laser Physics Centre, Research School of Physics and Engineering, Australian National University, Canberra, ACT 0200, Australia — [3]Center for Integrated Quantum Science and Technology (IQst), Ulm University, D-89081 Ulm, Germany

Single photon sources are essential for novel hybrid quantum systems and might be used in quantum network architectures, like the quantum repeater. The gain of Quantum Emitters in hexagonal Boron Nitride (hBN) are their promising characteristics such as persisting Fourier limited linewidths from cryogenic [1] up to room temperatures [2]. The suggested reason for this observation is the decoupling from in-plane phonon modes. Here, we present our recent results towards identifying the origin of this mechanical decoupling. They strengthen the assumption that the mechanical decoupling could be caused by out-of-plane emitters. The aim of our measurements is a better understanding of single quantum emitters in hBN, which could allow for implementation of novel hybrid quantum systems and quantum optics experiments at room temperature.

[1] A. Dietrich, et al., Phys. Rev. B 98, 081414 (2018)
[2] A. Dietrich, et al., arXiv:1903.02931.

Q 13.38 Mon 16:30 Empore Lichthof

Inverted plasmonic lens designs for ellipsometric form evaluations — •Tim Käseberg[1], Jana Grundmann[1], Thomas Siefke[1,2], Stefanie Kroker[1,3], and Bernd Bodermann[1] — [1]Physikalisch-Technische Bundesanstalt, 38116 Braunschweig, Germany — [2]Friedrich-Schiller-Universität Jena, Institute of Applied Physics, 07743 Jena, Germany — [3]Laboratory for Emerging Nanometrology, Technische Universität Braunschweig, 38106 Braunschweig, Germany

For a better sensitivity of polarization-based form information of nanostructures in Mueller matrix ellipsometry, we investigate the use of plasmonic lenses in ellipsometric setups. The classic plasmonic lens consists of a metallic slab with several nanoslits that function as waveguides for surface plasmon polaritons (SPPs). However, due to the need for narrow and deep slits leading to slab thicknesses of about 1 μm and slit widths around 10 - 100 nm, the fabrication of plasmonic lenses is challenging. We present a new design scheme, called inverted plasmonic lens, where instead of travelling through slits SPPs propagate through dielectric ridges with metallic sidewalls. The new design accommodates electron beam lithography, simplifying the fabrication process. In this contribution, we discuss this new design and compare it to the classic design. We used particle swarm optimization and finite element method to simulate lenses with different parameters to design a set of lenses for the application on varying regimes of wavelength and focal length. Additionally, we discuss the application of the inverted plasmonic lens in Mueller matrix microscopy for an advanced metrology of nanostructures with sub-wavelength sized features.

Q 13.39 Mon 16:30 Empore Lichthof

Investigating Electron-Phonon Coupling of Defect Centers in hBN — •Michael K. Koch[1], Andreas Dietrich[1], Michael Hoese[1], Igor Aharonovich[3], Marcus W. Doherty[2], and Alexander Kubanek[1,4] — [1]Insitute for Quantum Optics, Ulm University, D-89081 Ulm, Germany — [2]Laser Physics Centre, Australian National University, ACT 2601, Australia — [3]Faculty of Science, University of Technology Sydney, Ultimo, NSW 2007, Australia — [4]IQst, Ulm University, D-89081 Ulm, Germany

Single photon sources are key components for novel hybrid quantum systems, which will allow the implementation of quantum technologies like quantum repeaters or other quantum network architectures. Quantum emitters in hexagonal Boron Nitride (hBN) revealed promising attributes such as a homogeneous linewidth in agreement with the Fourier-Transform limit up to room temperature (RT) [1,2]. However, the full level structure including detailed characteristics of the phononic sideband lack full understanding. Here, we present our recent results leading to a more complete picture of single quantum emitters in hBN. We focus on the persistence of Fourier limited linewidths up to 300K. To examine the emitter level structure of the defect centers, we mainly use resonant (PLE) and off-resonant (PL) photoluminescence spectroscopy. Understanding the underlying physics for the persistence of Fourier limited lines up to room temperature paves the way for the development of novel hybrid quantum systems.

[1] A. Dietrich et al., Physical Review B 98, 081414(R) (2018)
[2] A. Dietrich et al., arXiv:1903.02931 (2019)

Q 13.40 Mon 16:30 Empore Lichthof

Nanomanipulation capabilities and optical coupling of intrinsically identical SiV^- color centers in nanodiamonds — •Elena Steiger[1], Richard Waltrich[1], Stefan Häussler[1], Konstantin Fehler[1], Lukas Antoniuk[1], Liudmila Kulikova[2], Valery Davydov[2], Viatcheslav Agafonov[3], Fedor Jelezko[1], and Alexander Kubanek[1] — [1]Institut für Quantenoptik, Universität Ulm, 89081 Ulm, Germany — [2]L.F. Vereshchagin Institute for High Pressure Physics, Russian Academy of Sciences, Moscow 142190, Russia — [3]GREMAN, UMR CNRS CEA 6157, Université F. Rabelais, 37200 Tours, France

Defects in solids, for instance the NV^- or the SiV^- color center in diamond have proven their usability in many applications that require single quantum systems. Nanodiamonds (NDs) featuring single color centers are one possible platform that enables a scalable use of such systems. Functionalizing the NDs for their use in quantum optics and photonics experiments however remains a challenge. We present NDs hosting single negatively-charged silicon-vacancy (SiV^-) centers featuring excellent optical properties, like a large Debye-Waller factor, close to Fourier-Transform limited linewidth and a narrow inhomogeneous distribution. We demonstrate nanomanipulation of the NDs, while conserving the optical properties denoting a first step towards the optical coupling of individual centers.

Q 13.41 Mon 16:30 Empore Lichthof

Hybrid assembly of quantum optical elements — •Andreas W. Schell — Leibniz University Hannover, Germany — PTB, Braunschweig, Germany

Bringing quantum technology from the laboratory to real world applications is a complex, but very rewarding, task. It will enable society to exploit the new opportunities the laws of quantum mechanics offer compared to purely classical physics. However, before the new quantum technology can be deployed, platforms to implement such a technology need to be discovered and developed. Here, we will show our ongoing efforts to implement such a platform using the so called hybrid approach for the assembly of quantum photonic elements. This approach is highly flexible and can be adapted to many different material systems and structures. In particular, we will introduce techniques based on scanning probe microscopy and three-dimensional laser writing. The hybrid quantum photonic elements assembled with these approached include emitter coupled to on-chip resonators and waveguides, different kinds of fiber integrated cavities and incorporate a variety of emitter such as NV centers, quantum dots, and defects in two-dimensional materials, such as hexagonal boron nitride. From these examples it can be seen that photonics elements assembled using hybrid techniques might help to facilitate the transition of quantum photonic networks out of lab to real-world applications.

Q 13.42 Mon 16:30 Empore Lichthof

Novel approaches for scanning probe sensing using color centers in diamond at ambient conditions — •Axel Hochstetter, Richard Nelz, and Elke Neu — Universität des Saarlandes, Fakultät NT - Fachrichtung Physik, Campus E2.6, 66123 Saarbrücken

The negatively charged nitrogen vacancy (NV) color center in diamond is a bright, photo-stable dipole emitter [1]. Due to its optically addressable spin states it is used for e.g. electrical and magnetic field sensing applications. In recent years, shallowly implanted NV centers in nanopillars have been introduced as scanning probes for high resolution imaging [2]. We showcase novel approaches for these probes to life-science applications. Specifically, the coupling of NV centers via Förster Resonance Energy Transfer (FRET) [3] unlocks new possibilities for all-optical sensing, as we demonstrate using 2-dimensional materials (e.g. WSe2 and graphene). Furthermore, we outline enhanced sensing schemes, using spin-to-charge conversion for NV centers in ambient conditions. [1] Radtke et al., arXiv:1909.03719(2019). [2] Appel et al., Rev. Sci. Instrum. 87 063703 (2016). [3] Nelz et al., Adv. Quantum Technol. 1900088(2019).

Q 13.43 Mon 16:30 Empore Lichthof

Molecular quantum optics on a chip — •Dominik Rattenbacher[1], Alexey Shkarin[1], Jan Renger[1], Tobias Utikal[1], Stephan Götzinger[2,1], and Vahid Sandoghdar[1,2] — [1]Max Planck Institute for the Science of Light (MPL), Erlangen, Germany — [2]Friedrich-Alexander University (FAU) Erlangen-Nürnberg, Erlangen, Germany

One-dimensional subwavelength waveguides (nanoguides) are very promising candidates for exploring the rich physics of quantum many body systems, since they allow one to couple several emitters, e.g. organic dye molecules, to a single one-dimensional light mode. However, the efficiency of coupling between an individual emitter and a realistic nanoguide is limited by geometric/material constrains and a rich internal level structure of the emitters. To address this issue, one can employ a high-finesse Fabry-Pérot cavity [1] to enhance the emission of molecules into the mode of interest. Here, we report on seven-times enhancement of the coupling by using microring resonators [2]. We report on our progress to improve our experimental platform by advances in the fabrication and the use of higher refractive index materials such as GaP. Together with the ability to manipulate the resonance frequencies of the molecules by static electric fields, we plan to investigate cooperative effects among several emitters [3].

[1] D. Wang et al., Nat. Phys. **15**, 483 (2019)
[2] D. Rattenbacher et al., New J. Phys. **21**, 062002 (2019)
[3] H. R. Haakh et al., Phys. Rev. A **94**, 053840 (2016).

Q 13.44 Mon 16:30 Empore Lichthof

Hybrid 2D material/dye molecule quantum emitter for negligible scattering-induced losses — •Sofia Pazzagli[1], Christian Liedl[1], Bita Rezania[1], Nikolai Severin[1], Jürgen Rabe[1,2], and Arno Rauschenbeutel[1] — [1]Institut für Physik, Humboldt-Universität zu Berlin, Newtonstr 15, 12489 Berlin, Germany — [2]IRIS Adlershof, Humboldt-Universität zu Berlin, Zum Großen Windkanal 6, 12489 Berlin, Germany

In this work we will present preliminary results on the development of a novel hybrid solid-state quantum emitter based on single dye molecules intercalated between two monolayers of transition metal dichalcogenides. The latter would provide almost perfect surface passivation and dye protection against photobleaching agents, as e.g. oxygen. Low spectral diffusion and an accordingly narrow and Fourier-limited emission linewidth at cryogenic temperatures of single molecules are expected and are investigated by optical means with a custom-built fluorescence confocal microscope. Being nanometre thin, this novel quantum emitter would be naturally prone to be efficiently couple to the evanescent field supported by nanophotonic devices, such as tapered optical fibers and on-chip high-Q microresonators. Strong light-matter interaction would be ensured as the emitter can be placed directly onto the surface of the nanostructure while causing only minimal scattering losses, hence representing a promising alternative to the currently available solid-state quantum emitters in sub-micrometric size crystals.

Q 13.45 Mon 16:30 Empore Lichthof

Reliable Nanofabrication for color center-based diamond sensors — •Dipti Rani, Oliver Opaluch, Richard Nelz, Mariusz Radtke, and Elke Neu — Saarland University, Campus E2.6, 66123 Saarbrücken

Individual, luminescent crystal defects in diamond, i.e. color centers, are stable, atomically sized quantum systems. Negative nitrogen vacancy (NV) centers represent isolated electronic spins that we manipulate using microwave radiation, while we read-out their spin state optically [1]. To enable nanoscale sensing, we incorporate NVs into highly functional photonic nanostructures. These tip-like structures enable scanning our NV centers close (< 50 nm) to a sample to record nanoscale resolution images e.g. of magnetic fields. We discuss our recent achievements in optimizing dedicated nanofabrication routines for our sensor devices which are crucial in the context of scalability as well as commercialization [2,3]. Results include a process optimizing adhesion of HSQ resists to diamond as well as the search for alternatives to HSQ. We furthermore address the influence of various plasma treatments on NV centers.

[1] M. Radtke et al., Arxiv 1909.03719 (2019)
[2] M. Radtke et al. Micromachines, 10, 718 (2019)
[3] M. Radtke et al., Opt. Mater. Express 9(12), 4716-4733 (2019)

Q 13.46 Mon 16:30 Empore Lichthof

Analysis of polarisation transfer in diamond from NV centers to ^{13}C assisted by P1 centers — •Marit Steiner, Benedikt Tratzmiller, and Martin Plenio — Institut für Theoretische Physik, Albert-Einstein-Allee 11, Universität Ulm, 89081 Ulm, Germany

A known approach to achieve nuclear hyperpolarisation, which has potential to improve the signal to noise ratio in many NMR applications significantly, is to use dynamic nuclear polarisation (DNP), the transfer of polarisation from electron spins to nuclear spins. NV centres in diamond are well known candidates for DNP on ^{13}C nuclear spins due to established initialisation and manipulation procedures, but the dipole dipole interaction between electron and nuclear spins is of low distance range. To provide more polarisation sources we propose to transfer polarisation from a polarised electron spin to nuclear spins assisted by other paramagnetic defects in diamond, like P1 centres that occur naturally in diamond. Furthermore, we analyse possible negative effects due to high P1 concentrations, since interaction between P1 centres could disturb the polarisation transfer from NV centre to ^{13}C, and modify the used DNP protocol to cancel out harmful effects. We use simulations to analyse the polarisation transfer from optically polarised NV centres to ^{13}C nuclei via P1 centres for few spins and derive a semi classical model to simulate the polarisation transfer and diffusion in a diamond.

Q 13.47 Mon 16:30 Empore Lichthof

High-resolution spectroscopy of single-molecule vibrational states in solid-state matrices — •Johannes Zirkelbach[1], Masoud Mirzaei[1], Tobias Utikal[1], Stephan Götzinger[1,2], and Vahid Sandoghdar[1,2] — [1]Max Planck Institute for the Science of Light, Erlangen, Germany — [2]Friedrich-Alexander University Erlangen-Nuremberg, Erlangen, Germany

We demonstrate a method to measure the linewidths of the vibrational levels of molecules at a high resolution. To achieve this, we populate the first excited state of single molecules using a narrow-band pump laser and monitor the depletion of the excited state population as the frequency of a second narrow-band 'dump' laser beam is tuned through the Stokes-shifted transitions to the vibrational levels of the electronic ground state. This allows us to resolve the linewidths of ground-state vibrational levels at a resolution of a few MHz limited by the wavemeter used. We apply this technique to dibenzoterrylene molecules embedded in para-dichlorobenzene and anthracene matrices at cryogenic temperatures down to 20 mK. We aim to search for potentially long-lived states, which might be interesting for coherent quantum operations.

Q 13.48 Mon 16:30 Empore Lichthof

Reduction of spectral diffusion by applying a sequence of optical control pulses — •Laura Orphal-Kobin[1], Joseph H. D. Munns[1], and Tim Schröder[1,2] — [1]Department of Physics, Humboldt-Universität zu Berlin, Berlin, Germany — [2]Ferdinand-Braun-Institut, Berlin, Germany

A quantum network could be realized by photon-mediated entanglement between stationary quantum bits (qubits). For the generation of coherent photons, enabling efficient entanglement operations, lifetime limited emission linewidths are a fundamental requirement.

However, for the negatively charged NV defect centre in diamond, natural linewidths (∼13 MHz) are challenging to achieve. In addition to homogeneous broadening, in particular the change of the optical transition frequency over time caused by fluctuations of the electrostatic environment leads to inhomogeneous broadening of the zero-phonon emission line (ZPL), which is referred to spectral diffusion.

While work is done on optimizing nanostructure designs and nanofabrication methods, active control schemes could be an interesting alternative to suppress spectral diffusion. Pulsed coherent control schemes are expected to modify the average rate of phase accumulated between the emitter states. By applying a sequence of optical π-pulses the ZPL could be stabilized at a target frequency given by the carrier frequency of the pulses.

Here, we present our work towards experimentally implementing an optical control protocol for reducing spectral diffusion of the ZPL of NV defect centres.

Q 13.49 Mon 16:30 Empore Lichthof

Optical Properties of Single Tin-Vacancy Centers in Diamond Nanopillars — •Joseph Munns[1], Cem Torun[1], Julian Bopp[1,2], Laura Orphal-Kobin[1], Natalia Kemf[2], Mathias Matalla[2], Ralph-Stephan Unger[2], Ina Ostermay[2], Alexander Külberg[2], Andreas Thies[2], and Tim Schröder[1,2] — [1]Humboldt-Universität zu Berlin, Berlin, Germany — [2]Ferdinand Braun Institut, Berlin, Germany

The tin-vacancy centre in diamond (SnV) has very recently attracted increasing interest as a promising system for quantum information protocols, as a candidate which may offer both the optical as well as the spin coherence properties needed for a robust spin-photon interface in a quantum node. Motivated by this, we present our progress towards investigating the feasibility of deploying the SnV for the generation of resource states for quantum communication protocols. First and foremost, this necessitates the ability to reliably generate and control single SnVs with the required properties. In this work, we therefore focus upon the characterisation of optical and spin coherence properties of SnVs, which are artificially generated with differing implantation strategies and integrated into diamond nanopillars. This enables a route to optimise the yield of nanopillar integrated single SnVs, and therefore provides a means to realise a scalable spin-photon quantum node.

Q 13.50 Mon 16:30 Empore Lichthof

Entanglement of High-Energy Photons — •Michael E. N. Tschaffon[1], Maxim A. Efremov[1,2], and Wolfgang P. Schleich[1,2] — [1]Institut für Quantenphysik, Universität Ulm, D-89069 Ulm, Germany — [2]Institut für Quantentechnologien, Deutsches Zentrum für Luft- und Raumfahrt (DLR), D-89077 Ulm, Germany

For decades, photons have been used extensively as a tool to verify in a laboratory many practical effects based on entanglement. Nowadays, pairs of such entangled photons are mostly produced for visible light by means of parametric down-conversion. However, many applications require sources operating in other domains such as the radio frequency or even the X-ray domain. We consider the decay of positronium (a bound state comprised of an electron and a positron) in its ground state as a new source of two high-energy entangled photons. The ground state is treated non-relativistically whereas the decay is examined perturbatively in the framework of QED. We investigate the degree of entanglement of the produced photons in both polarization and momentum.

Q 13.51 Mon 16:30 Empore Lichthof

Time emergence in the coherent state basis — •Sebastian Gemsheim and Jan-Michael Rost — Max-Planck-Institut für Physik komplexer Systeme, Dresden, Deutschland

Is time fundamental or emergent? This is an old question but to date the answer remains elusive. Advocating for the latter, we examine a possible mechanism for its emergence. The time-dependent Schroedinger equation can be obtained from the time-independent Schroedinger equation for a bipartite system [1], comprised of a quantum 'clock' and a generic quantum system. Consequently, the time parameter emerges from an underlying entanglement between both subsystems.

Specifically, we take a single harmonic oscillator as the 'clock' in the coherent state basis. This allows us to explore the significance of having two degrees of freedom in the complex plane which manifests itself as a complex time parameter. We derive a one-dimensional parametrized curve in the classical limit of large 'clock' energies, i.e., a one-dimensional real-time parametrization. To be operational as a clock, the 'clock' energy must be large in order to effectively distinguish between different 'clock positions' and we quantify the achievable, energy-dependent resolution. In addition, we investigate analogies and similarities to the imaginary-time formalism, e.g., imaginary-time propagation.

[1] J. S. Briggs, S. Boonchui, and S. Khemmani, Journal of Physics

A: Mathematical and Theoretical 40, 1289 (2007)

Q 13.52 Mon 16:30 Empore Lichthof

Bayesian inference of CSL-Parameters — •Björn Schrinski and Klaus Hornberger — Fakultät für Physik, Universität Duisburg-Essen, Duisburg

Collapse models [1] are a possible explanation for the absence of quantum mechanical superpositions on macroscopic scales. The most prevalent model is the Continuous Spontaneous Localization (CSL) model [2] being under intensified scrutiny in recent years [3]. While uninformative Bayesian parameter estimation can be applied to assess the degree to which a specific experiment verifies quantum mechanics on macroscopic scales [4], we show here how one can use the Bayesian approach to combine all experimental observations to obtain conservative exclusion regions in the CSL parameter space.

[1] Bassi et al., Rev. Mod. Phys. 85, 471 (2013)
[2] G.C. Ghirardi et al., Phys. Rev. A 42, 78 (1990)
[3] M. Carlesso et al., Springer Proceedings in Physics 237, 1 (2019)
[4] Schrinski et al., Phys. Rev. A 100, 032111(2019)

Q 13.53 Mon 16:30 Empore Lichthof

Phonon pair creation by tearing apart quantum vacuum fluctuations — •Florian Hasse[1], Deviprasath Palani[1], Frederick Hakelberg[1], Philip Kiefer[1], Matthias Wittemer[1], Ulrich Warring[1], Tobias Schaetz[1], Christian Fey[2], and Ralf Schützhold[3] — [1]Albert-Ludwigs-Universität Freiburg, Physikalisches Institut, Hermann-Herder-Strasse 3, 79104 Freiburg — [2]Universität Hamburg, Fachbereich Physik, Luruper Chaussee 149, 22761 Hamburg — [3]Institut für Theoretische Physik, Technische Universität Dresden, 01062 Dresden

We switch the trapping field of two ions sufficiently fast to tear apart quantum vacuum fluctuations and, thereby, create squeezed states of motion [1]. This process can be interpreted as an experimental analog to the particle pair creation during a cosmic inflation in the early universe [2] and is accompanied by the formation of entanglement in the ions' motional degree of freedom [3]. Hence, our platform allows studying the causal connections of squeezing, pair creation, and entanglement and might permit to cross-fertilise between concepts in cosmology and applications of quantum information processing.

[1] Wittemer, M. et al. Phys. Rev. Lett. 123, 180502 (2019).
[2] Schuetzhold, R. et al., Phys. Rev. Lett. 99, 201301 (2007)
[3] Fey, C. et al., Phys. Rev. A 98, 033407 (2018)

Q 13.54 Mon 16:30 Empore Lichthof

Topological Protection in non-Hermitian Haldane Honeycomb Lattices — Pablo Reséndiz-Vázquez[1], •Konrad Tschernig[2,3], Armando Perez-Leija[2,3], Kurt Busch[2,3], and Roberto de J. León-Montiel[1] — [1]Instituto de Ciencias Nucleares, Universidad Nacional Autónoma de México, Apartado Postal 70-543, 04510 Cd. Mx., México — [2]Max-Born-Institut, Max-Born-Straße 2A, 12489 Berlin, Germany — [3]Humboldt-Universität zu Berlin, Institut für Physik, AG Theoretische Optik & Photonik, D-12489 Berlin, Germany

Topological phenomena in non-Hermitian systems has recently become a subject of great interest in the photonics and condensed-matter communities. In particular, the possibility of observing topologically-protected edge states in non-Hermitian lattices has sparked an intensive search for systems where this kind of states is sustained. Here, we present the first study on the emergence of topological edge states in a two-dimensional Haldane lattice endowed with balanced gain and loss. We show that edge states can be observed in the trivial $\mathcal{PT}$-symmetric phase, that is, when the gain and loss are absent, as well as in the broken $\mathcal{PT}$-symmetric phase, that is, when the spectrum of the system's Hamiltonian is not entirely real. Remarkably, we find that this behavior is universal in the sense that any geometry of the lattice edge, namely zigzag, bearded or armchair supports edge states. These results demonstrate that two-dimensional topologically-protected edge states may exist even in the absence of $\mathcal{PT}$ symmetry.

Q 13.55 Mon 16:30 Empore Lichthof

Purcell-Enhanced Emission from Individual SiV- Center coupled to Photonic Crystal Cavity — •Niklas Lettner[1], Konstantin Fehler[1,2], Anna Ovvyan[3], Lukas Antoniuk[1], Nico Gruhler[4], Valery Davydov[5], Viatcheslav Agafonov[6], Wolfram H.P. Pernice[3], and Alexander Kubanek[1,2] — [1]Institute for Quantum Optics, Ulm University, Germany — [2]Center for Integrated Quantum Science and Technology (IQst), Ulm University, Albert-Einstein-Allee 11, Germany — [3]Institute of Physics and Center for Nanotechnology, University of Münster, Germany — [4]Karlsruhe Institute of Technology (KIT), Institute of Nanotechnology, Germany — [5]L.F. Vereshchagin Institute for High Pressure Physics, Russian Academy of Sciences, Troitsk, Russia — [6]GREMAN, UMR CNRS CEA 6157, Universit F. Rabelais, France

The combination of classical integrated photonic structures with color centers in diamond, like the Nitrogen Vacancy (NV^-) or the Silicon Vacancy (SiV^-) Center, offer a promising platform for on-chip quantum optics experiments. We combine silicon nitride photonic crystal cavities with color centers in nanodiamonds in a hybrid approach. We show the experimental results coupling NV centers efficently to a photonic crystal cavity mode [1] and the purcell enhanced emission of individual SiV^- centers in nanodiamonds with a Purcell factor of 4 [2]. In this poster we lay out the details of our experiments.

[1] Fehler, Konstantin G., et al. ACS Nano 2019, 13, 6, 6891-6898.
[2] Fehler, Konstantin G., et al. preprint arXiv:1910.06119 (2019).

Q 13.56 Mon 16:30 Empore Lichthof

The interaction of a three-level system with quantized light — •Hendrik Rose[1], Daria V. Popolitova[2], Olga V. Tikhonova[2], Polina R. Sharapova[1], and Torsten Meier[1] — [1]Department of Physics, University of Paderborn, Warburger Straße 100, D-33098 Paderborn, Germany — [2]Faculty of Physics, Moscow State University, Leninskie Gory, 1, Moscow, 119991 Russia

Light-matter interaction described with a fully quantized model provides the possibility of utilizing quantum correlations of light [1]. Especially the excitation of materials by nonclassical light can lead to new effects and applications [2] that can be of special interest for quantum metrology and quantum communication.

Our investigations were performed using a Jaynes-Cummings-like model with three electronic levels and two light states, where coherent and squeezed states were considered. Our system contains different loss mechanisms, namely, dephasing, cavity and radiative losses.

The energy level population dynamic was calculated, this dynamic is a unique signature, determined by the photon statistics. Electromagnetically induced transparency (EIT) is demonstrated with quantized light. Special features of the EIT regime were found in the case of excitation by squeezed light. Moreover, quantum correlations between fields were studied.

[1] P.R. Sharapova & O.V. Tikhonova, Quantum Electronics **42**, 199 (2012).
[2] K.V. Zapyantsev & O.V. Tikhonova, Bull. Russ. Acad. Sci. Phys. **82**, 1394 (2018).

Q 13.57 Mon 16:30 Empore Lichthof

Generating two-mode squeezing through measurement-induced nonlinearity — •Matvei Riabinin, Polina Sharapova, Tim J. Bartley, and Torsten Meier — University of Paderborn, Warburger Strasse 100, D-33098 Paderborn, Germany

In optics, nonlinear effects such as parametric down-conversion (PDC) can generate entangled states, quadrature squeezing, and other nonclassical effects. The generation of PDC typically requires strong light intensities since the efficiency of this effect is low. Another way of creating such nonlinear transformations in quantum optics is to use so-called measurement-induced nonlinearities, where nonlinear effects are acquired by applying detection. The advantage of using detection compared to PDC is that fewer incident photons are required to generate nonclassical effects, which makes detection useful at low photon number regime. Acquired effects, however, have a probabilistic nature. In our work, we model a two-mode interferometer where we input different states such as a coherent state and single-photon state and apply detection. We analyze the acquired nonclassical property such as two-mode squeezing at the output. We present an analytical solution for the quantum state at the output and show that detection leads to two-mode squeezing which is absent without detection. In the considered interferometer, it is also possible to generate quantum states similar to two-mode coherent state superposition with high fidelity. Also, we model potential losses inside the interferometer to analyze the possibility of the experimental implementation.

Q 13.58 Mon 16:30 Empore Lichthof

The discrete and continuous fractional Fourier transform applied to entangled two-photon states — •Malin Kück[1,2], Kurt Busch[1,2], and Armando Perez-Leija[1,2] — [1]Humboldt-Universität zu Berlin — [2]Max-Born-Institut, Berlin

Spontaneous parametric down-conversion (SPDC) is a nonlinear optical process that takes place in birefringent crystals where high-energy pump photons are converted into pairs of low-energy signal and idler photons. Depending on the crystal shape and the pump field the emerging photon pairs may exhibit a certain degree of correlation. In this contribution we use the fractional Fourier transform to externally tailor the correlations of photon pairs generated in SPDC sources. We show that arbitrary degrees of intensity correlations can be obtained by applying the Fourier transform of fractional orders to the output states of SPDC sources. In doing so, we compute the dynamics of two-photon light traversing discrete and continuous fractional Fourier transformers, that is, waveguide arrays and GRIN optical media. Moreover, we consider different entanglement criteria to characterize the evolving photon pairs.

Q 13.59 Mon 16:30 Empore Lichthof

Towards generation of Squeezed States of Light at the Rb D1 line — •Torben Sobottke[1,2] and Roman Schnabel[1,2] — [1]Universität Hamburg, Luruper Chaussee 149, 22761 Hamburg — [2]The Hamburg Centre for Ultrafast Imaging, Hamburg, Germany

The unique non-classical properties of squeezed states of light can be widely used, for example in quantum limited metrology, quantum communication, spectroscopy or microscopy. Within the cluster of excellence "Advanced Imaging of Matter", we started a project which aims at building a portable, tunable, continuous wave squeezed light source operating around the Rb D1 line, thus in the wavelength range from 795nm to 805nm. This device will be used to study the interaction of squeezed light with atoms, ultracold atom gases or BECs. In the poster, we will present the current design ideas, and will especially focus on the challenges to counteract radiation damage of the SHG and OPO due to the near-UV pump light.

Q 13.60 Mon 16:30 Empore Lichthof

A robust, compact ion-trap quantum computer — •Verena Podlesnic[1], Ivan Pogorelov[1], Thomas Feldker[1], Thomas Monz[1], Philipp Schindler[1], and Rainer Blatt[1,2] — [1]University of Innsbruck, Department of Experimental Physics, Technikerstraße 25/4, 6020 Innsbruck, Austria — [2]Institut für Quantenoptik und Quanteninformation der Österreichischen Akademie der Wissenschaft, Technikerstraße 21a, 6020 Innsbruck, Austria

Quantum computers promise to solve specific problems exponentially faster than today's classical computers. Especially trapped ions have been proven to be promising candidates for the realization of quantum computers as emphasized by the demonstration of high high-fidelity gates on a small number of physical quantum bits [1].

The objective of the project is to realize a robust and compact ion-trap quantum computer with scalable components that can be operated by non-specialist users. In the first iteration we are going to implement a linear Paul trap. In the long term a microfabricated multi-segment ion-trap with the capability of storing 50 $^{40}Ca^+$-qubits will be installed. Full control of these qubits is provided by simultaneous single-ion addressing via fiber arrays. All required components are going to be integrated with the the ion-trap apparatus in compact 19" racks.

Here, we will present the current status of the experimental setup.

[1]J. Benhelm, G. Kirchmair, C. Roos, R. Blatt "Towards fault-tolerant quantum computing with trapped ions", Nature Phys. 4 463 (2008)

Q 13.61 Mon 16:30 Empore Lichthof

Developments towards Microwave-driven high-fidelity Quantum logic gates in multilayer ion traps — •Jonathan Morgner[1,2], Giorgio Zarantonello[1,2], Nicolás Pulido[1,2], Henning Hahn[2,1], Amado Bautista-Salvador[2,1], and Christian Ospelkaus[1,2] — [1]Leibniz Universität Hannover, Institut für Quantenoptik — [2]Physikalisch-Technische Bundesanstalt, Braunschweig

Scalable quantum computation relies on a universal set of high-fidelity gate operations. Surface-electrode ion traps combined with the microwave near-field approach [1] are a promising candidate for both scalability and high-fidelity operations [2, 3].

In this poster, multiple developments for reducing radial mode errors are presented. A pulse shaped microwave two-qubit gate-scheme for resilience against radial mode instabilities is presented. Two-qubit gates with fidelities above 99.5% using this modulation-scheme were recently reported [4].

Furthermore, a setup - currently under construction - is presented, where Ar^+ bombardment will be used to clean the electrode surface from contaminants, which has been shown to reduce the heating rate of trapped ions [5].

References:
[1] C. Ospelkaus et al., Phys. Rev. Lett. 101 090502 (2008)
[2] T. P. Harty et al., Phys. Rev. Lett. 117, 140501 (2016)
[3] A. Bautista-Salvador et al., New. J. Phys. 21 043011 (2019)
[4] G. Zarantonello et al., arXiv:1911.03954 (2019)
[5] D. A. Hite et al., Phys. Rev. Lett. 109, 103001 (2012)

Q 13.62 Mon 16:30 Empore Lichthof

Coherent control of ions in a surface trap using Raman lasers — •Benjamin Wilhelm[1], Lukas Gerster[1], Pavel Hrmo[1], Martin van Mourik[1], Philipp Schindler[1], Thomas Monz[1], and Rainer Blatt[1,2] — [1]Institut für Experimentalphysik, Universität Innsbruck, Technikerstr. 25, 6020 Innsbruck, Austria — [2]Institut für Quantenoptik und Quanteninformation, Österreichische Akademie der Wissenschaften, Technikerstr. 21A, 6020 Innsbruck, Austria

Trapped atomic ions offer an advanced platform to realise universal gate operations for performing arbitrary quantum computation. One remaining major challenge is scaling up the number of qubits, such that quantum error correction on logical qubits may be performed. We use a cryogenically cooled planar surface trap with multiple trapping zones as an approach to overcome this challenge. This setup supports the confinement of two ion species, $^{40}Ca^+$ and $^{88}Sr^+$. By using the $^{40}Ca^+$-ion as an optical qubit, we are able to reach estimated coherence times up to 20 ms and create maximally entangled $^{40}Ca^+$-$^{40}Ca^+$ states with fidelities of 98.5(5) %. We plan on using the second species for recooling the motional modes of the ion string. Here we present a Raman beam setup to extend the coherent control of our system to ground state qubits.

Q 13.63 Mon 16:30 Empore Lichthof

EIT based storage and manipulation of light pulses with cold atoms in HCF — Wei Li[1,2], •Parvez Islam[1], Di Hu[1,2], and Patrick Windpassinger[1] — [1]Institut für Physik, Johannes-Gutenberg-Universität Mainz, Staudingerweg 7, 55128 Mainz, Germany — [2]School of Instrumentation and Opto-electronic Engineering, Beihang University, XueYuan Road 37, 100191 Beijing, P. R. China

Long distance quantum communications require the storage and on demand retrieval of qubits. A reliable light storage platform is using EIT to store light in the atomic coherence (spin waves). Combined with the potential of HCPCFs leads to enhanced light matter interaction and long-distance transport of quantum information. Furthermore, equipped with an optical conveyor belt, which can help transport the atomic ensembles, opens doors for realizing quantum registers by preparing a chain of atomic ensembles with stored photons.

We present our experiment of light storage and retrieval in an optical lattice. To this end we have successfully established storing in an optical lattice with storage times comparable to our transport times. The atomic ensemble is first loaded from a MOT and with the help of our optical conveyor belt transported into the hollow core fiber where we demonstrated successful storage of a light pulse. The storage has been optimized with the help of a circular polarized lattice along with a *magic* magnetic field and optical pumping to clock states. Subsequently, we aim to demonstrate light retrieval after transportation of the atomic ensemble through macroscopic distances.

Q 13.64 Mon 16:30 Empore Lichthof

Towards Cluster State Simulation of the (1+1)-dimensional Lattice Schwinger Model — •Stephan Schuster[1], Marc-Oliver Pleinert[1,2], and Joachim von Zanthier[1,2] — [1]Institut für Optik, Information und Photonik, Friedrich-Alexander-Universität Erlangen-Nürnberg (FAU), 91058 Erlangen, Germany — [2]Erlangen Graduate School in Advanced Optical Technologies (SAOT), Friedrich-Alexander-Universität Erlangen-Nürnberg (FAU), 91052 Erlangen, Germany

In recent years, several quantum simulations of complex physical systems have been performed [1,2]. In these simulations, the well-known quantum circuit model was implemented. This model of quantum computation is based on unitary operations applied onto qubits in a time-ordered sequence. The cluster state model - proposed by Raussendorf and Briegel - on the other hand, is an alternative, but equivalent model for quantum computation [3]. It avoids the complex gate realisations of the circuit model by performing the quantum computation through, potentially adaptive, projective measurements on a group of highly entangled multi-qubit states - the cluster states. Here, we investigate the possibility of the quantum simulation of the (1+1)-dimensional lattice

Schwinger model with such cluster states. Besides avoiding complex gate realisations, this might also offer a more efficient way for the simulation, since non-adaptive measurements on the different qubits commute and thus offer new perspectives on the parallelisability.

[1] Martinez et al.; Nature 534, 516 (2016). [2] Kokail et al.; Nature 569, 355 (2019). [3] Raussendorf et al.; PRL 86, 5188 (2001).

Q 13.65 Mon 16:30 Empore Lichthof

Estimating Error Rates of a Quantum Error Correction Code from its Syndromes — •Thomas Wagner, Martin Kliesch, Hermann Kampermann, and Dagmar Bruss — Heinrich-Heine-Universität Düsseldorf, Institute for Theoretical Physics 3

For near-term quantum devices, a precise characterization of the errors afflicting the device is crucial. Such a characterization can be used in quantum error correction to optimize decoders for the errors at hand, which significantly improves their performance. Information about the errors is usually obtained by benchmarking the device during calibration. However, for some quantum error correction codes it has been recently demonstrated that the syndrome statistics of the code itself also provides information about the errors. This is particularly interesting for online estimation of time varying error rates. In this work, we analytically characterize when parameters of a noise model can be identified from the syndrome statistics alone. Furthermore, we test numerical methods to perform this estimation in practice.

Q 13.66 Mon 16:30 Empore Lichthof

Operation of a microfabricated 2D ion trap array — •Marco Valentini[1], Silke Auchter[1,2], Philip Holz[1], Gerald Stocker[1,2], Kirill Lakhmanskiy[1], Clemens Rössler[2], Elmar Aschauer[2], Yves Colombe[1], and Rainer Blatt[1,3] — [1]Institut für Experimentalphysik, University of Innsbruck, Austria — [2]Infineon Technologies Austria AG, Villach, Austria — [3]Institut für Quantenoptik und Quanteninformation, Innsbruck, Austria

We investigate scalable surface ion traps for quantum simulation and quantum computing. We have developed a microfabricated surface trap consisting of two parallel contiguous linear trap arrays with 11 trapping sites each. An interconnected three-metal-layer structure provides addressing of the DC electrodes across the chip and shielding of the silicon substrate. The trap fabrication is carried out by Infineon in an industrial facility, which allows for complex electrode designs and ensures high process reproducibility. We demonstrate trapping and shuttling of multiple ions in the trap array, and form square and triangular ion-lattice configurations with up to six ions. We characterize stray electric fields and ion heating rates in several trapping sites, and report the observation of AC B field-induced shifts in the ions' energy levels. The design of the trap array allows for tuning of the inter-ion distance across the lattice, which we will use to demonstrate motional coupling of ions in neighboring sites.

Q 13.67 Mon 16:30 Empore Lichthof

Charakterisierung einer kryogenen Ionenfallen-Apparatur für skalierbare Quantenlogik — Jonas Schulz, •Max Werner, Janine Hilder, Daniel Pijn, Alexander Müller, Alexander Stahl, Björn Lekitsch, Ulrich Poschinger und Ferdinand Schmidt-Kaler — QUANTUM, Institut für Physik, Johannes Gutenberg-Universität Mainz

Kryogene Fallen bieten Vorteile für skalierbare Quantenlogik- Anwendungen: Die Reduzierung von Stoßraten mit dem Hintergrundgas erlaubt eine längere Lebensdauer der Ionen und verringertes Rauschen des elektrischen Feldes auf der Fallenoberfläche führt zu reduzierten Heizraten [1]. Wir präsentieren eine neue Apparatur, die mit einem Helium-Flusskryostat und der HOA-2 Oberflächenfalle des Sandia National Laboratory betrieben wird [2]. Die Falle verfügt über 130 Segmente für die Speicherung einer großen Zahl von qubits. Unsere Apparatur ist optimiert, um mit 40Ca+ Spin-Qubits [3] zu arbeiten, die eine reduzierte Sensitivität für mechanische Vibrationen aufweisen [4]. Wir beschreiben technische Besonderheiten des Aufbaus und präsentieren eine detaillierte Charakterisierung der thermischen Eigenschaften. Zudem zeigen wir erste Messungen mit gefangenen Ionen, wie die Ionenlebensdauer, Messungen der Fallenfrequenzen, Heizraten und Mikrobewegungskompensation.

[1] Brownnnutt et al., Rev. Mod. Phys. 87, 1419 (2015)
[2] Maunz, HOA Trap 2.0., SAND-2016-0796R 618951, (2016)
[3] Kaufmann et al,Phys. Rev. Lett. 119, 150503 (2017)
[4] Brandl et al., Rev. Sci. Instrum. 87, 113103 (2016)

Q 13.68 Mon 16:30 Empore Lichthof

Ion Trap Development for Scalable Quantum Computing — Alexander Müller, •Björn Lekitsch, Daniel Pijn, Janine Hilder, Alexander Stahl, Ferdinand Schmidt-Kaler, and Ulrich Poschinger — JGU Mainz, Institute for Physics, Staudingerweg 7, 55128 Mainz, Germany

We present the development of a new symmetric linear Paul trap for trapped-ion quantum computing. Scaling such a system to a few tens of qubits requires a precisely aligned and reliably fabricated ion trap, and also high optical access for laser and detection optics.

We show our work towards such a trap design making use of laser assisted etching of Quartz wafers in combination with physical vapor deposition and electroplating to create individual ion trap chips. We will discuss how two trap chips in combination with structured spacers can be aligned and permanently eutetically bonded together with μm precision using a die bonder. The trap will feature 40 usable electrode segments with an ion electrode distance of 350 μm.

To achieve addressing of single ions we will use both, ion shuttling [1] and individual optical addressing. For this we will equip two distinct trapping segments with full sets of cooling, gate, and detection lasers. One of these segments will feature a high-NA in-vacuum lens for efficient photon counting, and one will feature a high resolution objective for the individual addressing of large ion chains.

[1] D. Kielpinski et al., Nature 417, 709 (2002)

Q 13.69 Mon 16:30 Empore Lichthof

A fast multichannel arbitrary waveform generator for controlling quantum logic experiments based on trapped ion qubits — •Alexander Stahl[1], Björn Lekitsch[1], Janine Hilder[1], Daniel Pijn[1], Alexander Müller[1], Daniel Wessel[1], Matthias Romer[2], Stefan Ulm[2], Frank Ziesel[2], Ferdinand Schmidt-Kaler[1], and Ulrich Poschinger[1] — [1]Institut für Physik, Universität Mainz, Staudingerweg 7, 55128 Mainz, Germany — [2]AKKA DSW GmbH, Magirus-Deutz-Straße 2, 89077 Ulm, Germany

Shuttling ions in segmented radiofrequency traps offers a route to a scalable platform for quantum information processing. We present ongoing work towards extending an existing 80-channel fast multichannel arbitrary waveform generator (mAWG) towards capabilities for quantum error correction. In particular, data transfer protocols, new sequence data format and execution control software and hardware modules are established, which allow for fully generalized branched sequences: Both laser-driven qubit manipulation and ion shuttling operations can be carried out conditioned on in-sequence measurement results. Here, it is crucial to keep processing latencies small as compared to other relevant timescales. The real-time architecture, based on a Zynq system-on-a-chip, includes in-system evaluation and processing of fluorescence measurement data and an interface to a commercial radiofrequency AWG for controlling laser pulses. The architecture also includes a new version of the analog output hardware with improved electrical noise characteristics. The device will be commercialized in collaboration with AKKA technologies.

Q 13.70 Mon 16:30 Empore Lichthof

Using detector tomography to improve the simulation of quantum many-body dynamics on NISQ devices — •Jens Borgemeister — University of Siegen, Germany

On the poster I will present the current state of my work on using detector tomography and other error correction methods to improve the simulation of quantum many-body dynamics on current IBM quantum computers.