Q 39: Posters: Quantum Optics and Photonics III

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

Q 39.1 Wed 16:30 Empore Lichthof

A Distribution Board for an Ultra-stable Transportable Clock Laser — •Eileen Annika Klocke[1], Sofia Herbers[1,2], Lenard Pelzer[1], Uwe Sterr[1], Piet Oliver Schmidt[1,2,3], and Chrstian Lisdat[1] — [1]Physikalisch-Technische Bundesanstalt, Braunschweig, Germany — [2]DLR-Institute for Satellite Geodesy and Inertial Sensing, c/o Leibniz Universität Hannover, Hannover, Germany — [3]Institut of Quantum Optics, Leibniz Universität Hannover, Hannover, Germany

Ultra-stable interrogation lasers are key components in optical clocks. These clocks are used to investigate tests of fundamental physics or determine height differences between distant points in relativistic geodesy. Many applications require a transportable system that cannot rely on a well-controlled laboratory environment.

Here we present an interrogation laser system, composed of a laser, a cavity to frequency stabilize the laser, and a light distribution board. This system is designed for a transportable optical Al^+ quantum logic clock. The thermal noise of the cavity components is expected to limit the fractional frequency stability of the laser to values below 10^{-16}.

For clock operation, the laser light is split up on the distribution board, and sent via path length stabilized optical fibers to the atomic reference, the cavity and the frequency comb. The compact and robust distribution board ensures the transportability as well as a stable and accurate frequency transfer.

Q 39.2 Wed 16:30 Empore Lichthof

Investigation of zinc as a candidate for optical clocks — •David Röser, Maya Büki, and Simon Stellmer — Physikalisches Institut, Universität Bonn, Nussallee 12, 53115 Bonn

The development of modern optical clocks has lead to frequency references with a precision level down to about 10^{-18}. Much effort in current development is put into downsizing existing clocks to make them transportable while keeping their precision.

We investigate zinc atoms as a novel platform. Zinc provides metastable states and thus a suitable level structure with a narrow $^1S_0$ to $^3P_1$ intercombination line and a doubly forbidden clock transition in the UV range.

Its low sensitivity to blackbody radiation shifts and the potential for miniaturization could allow for clock operation outside of laboratory environments. A clock laser is currently developed by frequency quintupling a diode laser at telecom c-band wavelength enabling the direct distribution of the clock signal via optical fibers.

We report on different concepts of constructing a clock based on zinc spectroscopy and the status of our experiment.

Q 39.3 Wed 16:30 Empore Lichthof

Steady-state superradiance for active optical clocks — •Francesca Fama[1], Sheng Zhou[1], Shayne Bennetts[1], Chun-Chia Chen[1], Rodrigo Gonzalez-Escudero[1], Benjamin Pasquiou[1], Florian Schreck[1], and the iqClock consortium[2] — [1]Institute of Physics, University of Amsterdam, Amsterdam, The Netherlands — [2]www.iqclock.eu

Superradiant lasers have been proposed as a next generation optical atomic clock for precision measurement, metrology, quantum sensing and exploration of new physics [1]. Recently, a pulsed superradiant laser was demonstrated using the ^{87}Sr clock transition [2], but a clock with millihertz stability requires steady-state operation.

We will describe the new machine that we are constructing, which aims to produce a steady-state superradiant laser for future time standards. The architecture is an improvement of our earlier work [3,4,5] where we have now demonstrated ideal sources for pumping a steady-state superradiant laser. We have produced a steady-state atomic beam guided by a dipole laser with a radial temperature of 1μK, a phase-space density of 10^{-4} and a flux of 3x10^7 ^{88}Sr/s. These performances have been explored also by using the ^{87}Sr isotope, which is of particular interest for clocks.

[1] Meiser et al., PRL 102, 163601 (2009). [2] Norcia et al., Sci Adv 2, 10, e1601231 (2016). [3] Bennetts et al., PRL 119, 223202 (2017). [4] Chen et al., PRA, 100, 023401 (2019). [5] Chen et al., arXiv:1907.02793 (2019).

Q 39.4 Wed 16:30 Empore Lichthof

Highly stable, compact components for a transportable Al^+/Ca^+ quantum logic optical clock — •Benjamin Kraus[1,4], Stephan Hannig[1,4], Moritz Mihm[2], Ortwin Hellmig[3], Patrick Windpassinger[2], and Piet O. Schmidt[1,4] — [1]Physikalisch-Technische Bundesanstalt, 38116 Braunschweig, Germany — [2]Johannes Gutenberg-Universität Mainz, 55122 Mainz, Germany — [3]Universität Hamburg, 20148 Hamburg, Germany — [4]DLR-Institute for Satellite Geodesy and Inertial Sensing, c/o Leibniz Universität Hannover, Welfengarten 1, 30167 Hannover, Germany

A transportable optical ion clock requires a compact and robust setup. These requirements are fulfilled by fiber-coupled components and rigid Zerodur®-based breadboards[1]. We present a distribution board, where light required for Ca^+ ionization, cooling and repumping is coupled into an LMA fiber. Moreover, we present a fiber-coupled length-stabilized source for Al^+ clock light of 267 nm, consisting of two subsequent single-pass SHG stages. Finally, we report on the development of fiber-coupled single and double-pass AOMs for that wavelength.

1. M. Mihm, "ZERODUR® based optical systems for quantum gas experiments in space," Acta Astronautica 159, 166*169 (2019).

Q 39.5 Wed 16:30 Empore Lichthof

Spin squeezing can only improve clocks with small atom number — •Marius Schulte[1], Christian Lisdat[2], Piet O. Schmidt[2,3], Uwe Sterr[2], and Klemens Hammerer[1] — [1]Institute for Theoretical Physics and Institute for Gravitational Physics (Albert-Einstein-Institute), Leibniz University Hannover — [2]Physikalisch-Technische Bundesanstalt (PTB), Braunschweig — [3]Institute for Quantum Optics, Leibniz University Hannover

We show that the stability of an optical atomic clock can not be improved by spin squeezed states for ensembles above a critical particle number as in this case, the optimum stability is completely determined by the noise and the limited coherence time of the interrogation laser. Our results apply to the common case of cyclic Ramsey interrogations on a single atomic ensemble with dead time between each measurement. The combination of analytical models for projection noise, dead time noise (Dick effect) and laser phase noise allows quantitative predictions of the critical particle number and the optimal clock stability for a given dead time and laser noise. Our analytical predictions are confirmed by numerical simulations of the closed servo loop of an optical atomic clock. This work was supported by SFB 1227 'Dq-mat'. arXiv:1911.00882

Q 39.6 Wed 16:30 Empore Lichthof

Resonance fluorescence of trapped Be^{9+} ions — •Aleksei Konovalov and Giovanna Morigi — Universität des Saarlandes, Saarbrücken, Germany

We theoretically analyse the resonance fluorescence of a single Be^9+. We consider the transition $2s_{1/2} \rightarrow 2p_{3/2}$ including the hyperfine structure and analyse the photon signal using the coarse-grained master equation developed in [1], which consistently includes interference terms between parallel dipolar transitions. We discuss the effect of these interference terms on the spectroscopic signal.

[1] Andreas Alexander Buchheit and Giovanna Morigi, PHYSICAL REVIEW A 94, 042111 (2016).

Q 39.7 Wed 16:30 Empore Lichthof

Progress towards an indium multi-ion clock — •Hartmut Nimrod Hausser, Tabea Nordmann, Jan Kiethe, Leon Schomburg, and Tanja E. Mehlstäubler — Physikalisch-Technische Bundesanstalt, Bundesallee 100, 38116 Braunschweig, Germany

Multi-ion clocks face many challenges: One of the biggest challenge is the strong electric field gradient leading to a relatively high electronic quadrupole shift. For such a clock $^{115}In^+$ is an ideal candidate offering an extremely small electric quadrupole moment, a narrow-line clock transition, a transition where it is directly detectable and low systematic shifts [1]. Here we present the progress towards an indium multi-ion clock. We show the first steps towards automatization like automated fiber coupling and slave relocking. A small chip-based linear Paul trap is used to trap $^{115}In^+$ and $^{172}Yb^+$ in a mixed Coulomb crystal [2]. We show the implementation of a new detection system

where both species can be imaged simultaneously. We present further investigations on polarization-maintaining UV fibers to deliver a Gaussian-like, intensity- and polarization-stable beam to the ions at 230.6 nm and 236.5 nm, which are the detection and clock transition wavelength of $^{115}In^{+}$, respectively.

This project has received funding from the European Metrology Programme for Innovation and Research (EMPIR) co-financed by the Participating States and from the European Union's Horizon 2020 research and innovation programme (Project No. 18SIB05 ROCIT).

[1] N. Herschbach et al., *Appl. Phys. B* **107**, 891-906 (2012).
[2] J. Keller et al., *Phys. Rev. A.* **99**, 013405 (2019).

Q 39.8 Wed 16:30 Empore Lichthof

Laser light shaping and control for precision spectroscopy with ions — •Robin L. Stampa, André P. Kulosa, Chih-Han Yeh, Dimitri Kalincev, Henning A. Fürst, Laura S. Dreissen, and Tanja E. Mehlstäubler — Physikalisch-Technische Bundesanstalt, Bundesallee 100, 38116 Braunschweig, Germany

Coherent excitation of forbidden transitions, as used for example in optical clocks, sets stringent requirements on the ultra-stable probe laser. To provide sufficient power, the light source needs to be amplified. This can be accomplished by a slave diode laser. Here, we report on automatic re-locking of a slave laser at 411 nm employing a microcontroller for nearly 24/7 operation [1]. To reach the accuracy of optical clocks with efficiently reduced measurement time, simultaneous precision spectroscopy of forbidden transitions in trapped multi-ion Coulomb crystals can be advantageous. This requires equally distributed laser intensity onto the ions. We investigate different methods for this, while taking flexibility, reliability, and ion-light interaction efficiency into account, using either a spatial light modulator, micromirror arrays or holographic phase plates. Our result will not only be of interest for the operation of optical multi-ion clocks, but also for the study of dynamics in multi-ion Coulomb crystals [2]. Furthermore, it can be an important tool for the test towards Local Lorentz Symmetry breaking with multiple ions [3].

[1] B. Saxberg et al., *Rev. Sci. Instrum.* **87**, 063109 (2016). [2] J. Kiethe et al., *Nat. Commun.* **8**, 15364 (2017). [3] R. Shaniv et al., *Phys. Rev. Lett.* **120**, 103202 (2018).

Q 39.9 Wed 16:30 Empore Lichthof

An ultra-stable resonator with a fundamental instability of 3×10^{-17} — •Steffen Sauer[1], Sebastian Häfner[2], Dominika Fim[1], Nandan Jha[1], Waldemar Friesen-Piepenbrink[1], Klaus Zipfel[1], Thomas Legero[2], Wolfgang Ertmer[1], Uwe Sterr[2], and Ernst Rasel[1] — [1]Institut für Quantenoptik, Hannover, Deutschland — [2]Physikalisch-Technische Bundesanstalt, Braunschweig, Deutschland

Most of today's accurate and stable optical clocks are limited by the so-called Dick noise, where the coherence length of the interrogation laser plays the decisive role. Therefore we are setting up a new 48 cm ULE resonator at room-temperature with crystalline mirror coatings [1] at 1550 nm. We expect a fundamental instability, caused by the Brownian motion in the material, of 3×10^{-17}, which is comparable to the most stable resonators in the world today. After the construction and characterization against the single-crystal silicon resonators at PTB [2], the ultra-stable resonator is to be used as ultra-stable local oscillator for the magnesium lattice clock at IQ, Hannover. The stability will be transmitted via a femtosecond fiber comb to the interrogation laser at 916 nm which currently operates with an instability of 4×10^{-16} in 1 s. On this poster we report on the progress and characterization of our ultra-stable local oscillator. This work has received funding under Germany's Excellence Strategy-EXC-2123/1 ("QuantumFrontiers").

[1] Cole et al., Nature Photonics **7**, 644-650 (2013)
[2] Matei et al., Phys. Rev. Lett. **118**, 263202 (2017)

Q 39.10 Wed 16:30 Empore Lichthof

Segmented linear multi-ion traps for a next generation of transportable high-precision optical clocks — •Florian Köppen[1], Hendrik Siebeneich[1], Pedram Yaghoubi[1], Michael Johanning[1], Alexandre Didier[2], Malte Brinkmann[2], Stefan Brakhane[3], Tanja Mehlstäubler[2], Dieter Meschede[3], and Christof Wunderlich[1] — [1]Naturwissenschaftlich-Technische Fakultät, Department Physik, Universität Siegen, Walter-Flex-Str. 3, 57072 Siegen, Germany — [2]Physikalisch-Technische Bundesanstalt, Bundesallee 100, 38116 Braunschweig, Germany — [3]Institut für Angewandte Physik der Universität Bonn, Wegelerstr. 8, 53115 Bonn, Germany

Trapped atomic ions are well suited for realizing accurate and stable optical clocks. The *opticlock* consortium [1] develops a compact transportable optical clock for non-specialist users, utilizing a quadrupole transition with a wavelength near 436 nm in a single $^{171}Yb^{+}$ ion, with a projected uncertainty of order 10^{-16}. Based on this system we develop a next-generation optical clock along [2] combining the accuracy of a multiple ion frequency standard with the compactness of the *opticlock*-demonstrator. For this purpose we use a segmented four layer ion trap and a compact vacuum interface, allowing for excellent optical access. We will present details of the chip carrier, chamber and cuvette, as well as the optical, electrical and software design.

[1] https://www.opticlock.de; *opticlock* is supported by the bmbf under grant no. 13N14385.
[2] J. Keller et al., Phys. Rev. A99, 013405 (2019)

Q 39.11 Wed 16:30 Empore Lichthof

Accelerating magnetic field sensing using optimized pulses on NV centers — •Jan Thieme, Ricky-Joe Plate, Josselin Bernardoff, Daniel Basilewitsch, Christiane Koch, and Kilian Singer — Institut für Physik, Uni Kassel, Deutschland

Estimation of physical parameters, such as a magnetic field on a spin, are very often done using the Ramsey method of separated fields for its utmost simplicity and optimality. More sophisticated scheme, using resources such as entanglement to enhance sensitivity achieve records for long measurement times.

We are looking for improvement using pulse sequences that decrease measurement time at the cost of a limited resolution. Indeed, optimal control tools can find pulse shapes, such as a square response - within limitation on hardware -, as a function of detuning which changes the way a resonance search is performed. The protocol's sensitivity can be evaluated using standard tools of estimation theory, in particular the Fisher information.

Such a protocol could for instance allow imaging to be performed on shorter timescales.

Q 39.12 Wed 16:30 Empore Lichthof

Perspectives for fundamental experiments with nanostructured optical cavities: From thermal quanta to general relativity — •Johannes Dickmann[1,2,3], Steffen Sauer[1,4], Sebastian Ulbricht[1,2,3], Robert Alexander Müller[1,2,3], Jan Meyer[1,2,3], Tim Käseberg[2], Mariia Matiushechkina[1,4], Andrey Surzhykov[1,2,3], Ernst Maria Rasel[1,4], Michèle Heurs[1,4,5], and Stefanie Kroker[1,2,3] — [1]Exzellenzcluster QuantumFrontiers, Hannover and Braunschweig, Germany — [2]Physikalisch-Technische Bundesanstalt, Braunschweig, Germany — [3]Technische Universität Braunschweig, Braunschweig, Germany — [4]Leibniz Universität Hannover, Hannover, Germany — [5]Max Planck Institute for Gravitational Physics, Hannover, Germany

High finesse optical cavities are the key ingredients for the world's most precise measurements. These range from optical atomic clocks via quantum optomechanics up to gravitational wave detection. Improving the stability of optical cavities paves the way for the next frontiers of scientific discoveries. Recent mirror technologies based on nanostructured surfaces are very promising to enhance the stability of optical cavities towards a range where quantum effects and the influence of gravity become apparent. We present theoretical considerations on gravitational effects on the optical output of ground-based cavities as well as discussions on thermal fluctuations using thin membranes in cavities. Proposed experimental configurations including design guidelines to measure temperature via thermal fluctuations and to test general relativity on earth complement this contribution.

Q 39.13 Wed 16:30 Empore Lichthof

Laser system and imaging optics for producing, cooling and detecting a $^{9}Be^{+}$ ion in a cylindrical Penning trap — •Frederik Jacobs[1], Teresa Meiners[1], Johannes Mielke[1], Matthias Borchert[1,3], Julian Pick[1], Juan M. Cornejo[1], Malte Niemann[1], Stefan Ulmer[3], and Christian Ospelkaus[1,2] — [1]Institut für Quantenoptik, Leibniz Universität Hannover — [2]Physikalisch Technische Bundesanstalt, Braunschweig — [3]Ulmer Fundamental Symmetries Laboratiory, RIKEN, Wako, Saitama 351-0198, Japan

The BASE collaboration aims for high precision measurements of the proton's and antiproton's g-factor to support tests of CPT invariance with baryons. We discuss an experimental setup for the development of laser-based manipulation techniques amenable to (anti-)protons trapped in a cylindrical Penning trap. The setup focuses on sympathetic cooling with a co-trapped laser-cooled beryllium ion.

Here, we present the optical setup for producing, cooling, and detecting a beryllium ion. The Doppler cooling beam is currently sent into the trap at a 45° angle with respect to the symmetry axis in order to cool both the radial and axial motional modes of the beryllium ion at the same time. We discuss an alternative approach based on an axial cooling beam and indirect cooling of the radial motional modes using only axialisation.

Q 39.14 Wed 16:30 Empore Lichthof

High-Q monolithic inertial sensors for seismic control in gravitational wave detectors — Sina Maria Köhlenbeck[1,2], •Jonathan Carter[1,2], Gerhard Heinzel[1,2], and Oliver Gerberding[3] — [1]MPI für Gravitationsphysik, Callinstr. 38, 30167 Hannover — [2]Institut für Gravitationsphysik, Leibniz Universität Hannover, Callinstr. 38, 30167 Hannover — [3]Institut für Experimentalphysik, Universität Hamburg, Luruper Chaussee 149, 22761 Hamburg

Seismic noise is one of the noise sources limiting the performance of earth-bound interferometric gravitational wave detectors. To enhance the operation time of future detectors, new sensors for active stabilization of the mirror displacement are required. Commercial sensors are heavy, bulky and not vacuum compatible, where our design, based on an all-glass opto-mechanic oscillator with an interferometric read-out, resolves these constraints. The concept, design and first tests of the oscillators will be presented.

Q 39.15 Wed 16:30 Empore Lichthof

Rydberg quantum optics in an ultracold Rubidium gas — •Hannes Busche, Nina Stiesdal, and Sebastian Hofferberth — University of Southern Denmark, Odense, Denmark

Mapping the strong interaction between Rydberg excitations in ultracold atomic ensembles onto single photons enables the realization of optical nonlinearities which can modify light on the level of individual photons. This approach forms the basis of a growing Rydberg quantum optics toolbox, which already contains photonic logic building-blocks such as single-photon sources, switches, transistors, and two-photon gates.

Here we discuss how we experimentally implement a 1d chain of Ryderg superatoms, each formed by an individually trapped atomic cloud containing ca. N=10000 atoms. With this system we can study the dynamics of single two level systems strongly coupled to quantized propagating light fields. The directed emission of the superatoms back into the probe mode makes this free-space chain of superatoms identical to emitters coupled to a 1d optical waveguide, thus realizing a cascaded quantum system coupled to a single probe mode.

Q 39.16 Wed 16:30 Empore Lichthof

Rydberg quantum optics in ultracold Ytterbium gases — •José Navarrete, Thilina Senaviratne, Mohammad Noaman, and Sebastian Hofferberth — University of Southern Denmark, Odense, Denmark

Mapping the strong interaction between Rydberg excitations in ultracold atomic ensembles onto single photons enables the realization of optical nonlinearities which can modify light on the level of individual photons. In our group, we explore this novel approach to realize effective photon-photon interaction in multiple experiment setups and following two complementary approaches employing Rydberg polaritons and superatoms.

Here we present progress with our new Rydberg quantum optics experiment utilizing ultracold Ytterbium as optical medium. The specific goal of this new setup is to study the interactions between a large number of Rydberg polaritons simultaneously propagating through a medium with extremely high atomic density. Employiing for the first time ultracold Ytterbium, an alkaline-earth-like element, for Rydberg quantum optics experiments offers unique advantages towards this goal. We discuss details of our experimental implementation and report on the progress towards observation of few-photon nonlinearities in Yb.

Q 39.17 Wed 16:30 Empore Lichthof

Interacting Polaritions in a Rydberg EIT Medium — •Annika Tebben[1], André Salzinger[1], David Grimshandl[1], Carlos Brandl[1], Sebastian Geier[1], Titus Franz[1], Nithiwadee Thaicharoen[1], Clément Hainaut[1], Gerhard Zürn[1], Thomas Pohl[2], and Matthias Weidemüller[1,3] — [1]Physikalisches Institut, Ruprecht-Karls Universität Heidelberg, Im Neuenheimer Feld 226, 69120 Heidelberg, Germany — [2]Department of Physics and Astronomy, Aarhus University, Ny Munkegade 120, DK 8000 Aarhus C, Denmark — [3]National Laboratory for Physical Sciences at Microscale and Department of Modern Physics, and CAS Center for Excellence and Synergetic Innovation Center in Quantum Information and Quantum Physics, Shanghai Branch, University of Science and Technology of China, Shanghai 201315, China

Polaritons, which are superpositions of a photonic and a collective atomic excitation, can interact via dressing to long-range interacting Rydberg states. This opens the possibility for investigating many-body physics with photons as well as strongly correlated states of light. For observing these effects strong interactions or large interaction times are needed. However, the latter is usually limited by the propagation time of the slow light polariton through the medium under conditions of electromagnetically induced transparency (EIT). We show that this limitation can be overcome by generating propagation free photonic excitations, so called stationary light polaritons, and explain how this kind of polaritons can serve to engineer strongly interacting many body systems.

Q 39.18 Wed 16:30 Empore Lichthof

Rydberg excitation of trapped ions for quantum simulation and computation — •Justas Andrijauskas[1,2], Jonas Vogel[1], Arezoo Mokhberi[1], and Ferdinand Schmidt-Kaler[1,2] — [1]Institut für Physik, Universität Mainz, D-55128 Mainz, Germany — [2]Helmholtz-Institut Mainz, D-55128 Mainz, Germany

Trapped ions excited to Rydberg states combines high controllability of trapped ions with high polarisability and long lifetimes of Rydberg states[1,2]. We present the two step excitation of trapped $^{40}Ca^{+}$ ions to Rydberg states, using laser systems at 213nm and 287nm wavelengths. Laser beams are configured in counter-propagating manner such that the line broadening due to the Doppler effect is mitigated. The ion trap is operated at 14.6 MHz drive frequency and features secular frequencies near 600, 1200, 1600 kHz. We also discuss our experimental results obtained by spectroscopy of S and D series in order to optimize the micromotion control, determine line shapes and quantum defects[3] and compare to theory predictions.

[1] Feldker et al., Phys. Rev. Lett. 115, 173001(2015)
[2] Higgins et al., Phys. Rev. Lett. 119, 220501 (2017)
[3] Mokhberi et al. J. Phys. B 52, 214001 (2019)

Q 39.19 Wed 16:30 Empore Lichthof

Towards a Photon-Photon Quantum Gate Using Rydberg-Interactions in an Optical Resonator — •Thomas Stolz, Steffen Schmidt-Eberle, Lukas Husel, Stephan Dürr, and Gerhard Rempe — Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Str. 1, 85748 Garching, Germany

We recently realized a photon-photon π-phase gate based on free-space Rydberg EIT in an ultracold atomic ensemble [1]. The performance in terms of efficiency and postselected fidelity is limited by dephasing resulting from the interaction between the Rydberg electron and surrounding ground-state atoms. The dephasing rate can be much reduced by working at lower atomic density [2]. To keep the gate operational in this regime, we plan to place the ensemble inside a moderate-finesse optical resonator [3,4]. We report on experimental progress toward this goal.

[1] D. Tiarks et al. Nat. Phys. **15**, 124 (2019). [2] S. Schmidt-Eberle et al. arXiv:1909.00680. [3] Y. M. Hao et al. Sci. Rep. **5**, 10005 (2015). [4] S. Das et al. PRA **93**, 040303 (2016).

Q 39.20 Wed 16:30 Empore Lichthof

Ultrafast Ionization of a BEC: Highly Charged to Neutral Microplasma — •Mario Neundorf[1,2], Tobias Kroker[1,2], Julian Fiedler[1], Julia Bergmann[1], Markus Drescher[1,2], Klaus Sengstock[1,2], Philipp Wessels[1,2], and Juliette Simonet[1,2] — [1]Zentrum für Optische Quantentechnologien (ZOQ), Luruper Chaussee 149, 22761 Hamburg — [2]The Hamburg Centre for Ultrafast Imaging (CUI), Luruper Chaussee 149, 22761 Hamburg

In our experiment, we combine a ^{87}Rb Bose-Einstein condensate with femtosecond laser pulses to investigate collective non-equilibrium dynamics after locally ionizing parts of the atomic cloud.

The quantum gas machine allows to simultaneously detect atoms, ions and electrons after photoionization and resolves the kinetic energy of the charged particles.

By using a micrometer sized waist for the ionizing laser, we can trigger ultracold plasmas with variable particle numbers. Tuning the initial

kinetic energy of the ionization products allows bridging from highly charged to neutral plasmas.
The combination of a well-controlled target with negligible initial kinetic energy and the small system size allows us to simulate the underlying dynamics with charged particle tracing. This provides an excellent model system to study the experimentally demanding density regime between ionized solid-state nanoclusters and ultracold neutral plasma.

Q 39.21 Wed 16:30 Empore Lichthof

Towards a strontium Rydberg laser for quantum simulation with tweezer arrays — •Thies Plassmann, Shayne Bennetts, Alex Urech, Benjamin Pasquiou, Robert Spreeuw, and Florian Schreck — Institue of Physics, University of Amsterdam, Amsterdam, The Netherlands

We are developing a broadly tunable CW UV-laser system for exciting Rydberg states in strontium atoms. Arrays of single atoms in tweezer traps using Rydberg states for long-range interactions has proven to be a powerful platform for quantum simulation and computation. The rich internal structure of fermionic strontium combined with the second valence electron in alkaline-earth atoms offers exciting new possibilities. However, generating Rydberg states via the metastable $^3P_{0,1,2}$ intermediate states requires an ultraviolet wavelength around 319 nm. Furthermore, exploiting the whole $^3P_{0,1,2}$ manifold requires a tunability of 22 THz, a linewidth of 100 kHz and around 0.25 W of power. This poses a challenge in terms of laser design.

We will describe our progress towards developing such a laser system. Our tunable laser architecture, based on [1], begins with 1.58-μm and 1.07-μm external cavity diode lasers followed by 5-W fiber amplifiers. Sum frequency generation in PPLN generates a 638-nm output, which is then doubled to 319 nm with a resonant BBO cavity. By stabilizing to an atomic-referenced optical transfer cavity we hope to reach linewidths around 100 kHz.

[1] E. M. Bridge et al. Opt. Express 24, 2281 (2016).

Q 39.22 Wed 16:30 Empore Lichthof

Three-Photon Electromagnetically Induced Transparency with Cold Rydberg Atoms — Yagiz Oyun[1], Ozgur Cakir[2], and •Sevilay Sevincli[1] — [1]Izmir Institute of Technology, Department of Photonics, 35430 Urla, Izmir, Turkey — [2]Izmir Institute of Technology, Department of Physics, 35430 Urla, Izmir, Turkey

Electromagnetically induced transparency (EIT) is a quantum coherence phenomenon, in which different excitation paths interfere destructively, canceling out the absorption of the medium for probe laser. Rydberg-EIT media have been used for different applications to gain better understanding of quantum many body interactions since EIT was observed with Rydberg atoms in a two-photon excitation scheme. Dressed state EIT in a four-level scheme was realized experimentally with thermal Cs atoms[1] recently. We investigate three-photon EIT in a cold atomic ensemble by proposing a self-consistent mean-field approach to understand the interaction effects on this system. We also apply the rate equation method to investigate the nonlinear properties of the system. We observed that as the interaction strength increases, transparency weakens as in the two-photon Rydberg-EIT systems, and transparency window broadens and shifts away from the resonance. We acknowledge support from Scientific and Technological Council of Turkey (TUBITAK) Grant No. 117F372.

[1] N. Sibalic, J. M. Kondo, C. S. Adams, K. J. Weatherill, Phys. Rev. A. 94, 033840 (2016).

Q 39.23 Wed 16:30 Empore Lichthof

Ghost Polarization Communication — •Markus Rosskopf, Till Mohr, and Wolfgang Elsässer — Institute of Applied Physics, Technische Universität Darmstadt, Schlossgartenstraße 7, 64289 Darmstadt, Germany

The polarization state of polarized light is typically quantified by a Stokes vector on the Poincaré sphere. Completely unpolarized light can be understood as a rapidly altering Stokes vector, with an instantaneous polarization state, that can be characterized by a polarization time which is in the femtosecond regime and can be measured by a photomultiplier detecting two-photon absorption.

Recently, ghost imaging has been extended to new ghost modality domains, in particular ghost spectroscopy and ghost polarimetry (GP) by exploiting correlations in the spectral and polarization domain, respectively. In GP, a hidden polarization state has been successfully recovered by exploiting polarization correlations.

Here, we demonstrate a novel communication scheme between two parties by encoding and camouflaging information in the instantaneous polarization state of unpolarized light emitted by an erbium-doped fiber amplifier. The 2nd order intensity correlation is measured using two-photon absorption interferometry and used to retrieve the transmitted polarization state and thus the message.

The correlation measurements for unpolarized light in our ghost polarization communication setup can be seen in analogy to classical intensity measurements of polarized light using Stokes parameter analysis, thus also offering new insight into the nature of unpolarized light.

Q 39.24 Wed 16:30 Empore Lichthof

Towards fabrication and optimization of LNOI nano-waveguides — •Laura Bollmers, Laura Padberg, Sebastian Lengeling, Christof Eigner, and Christine Silberhorn — Universität Paderborn, Integrierte Quantenoptik, Warburger Str. 100, D-33098 Paderborn

Lithium niobate on insulator (LNOI) is a material platform of growing interest. Thin-film of lithium niobate currently revolutionizes the old lithium niobate platform since it allows for the miniaturization of devices. Especially the nano-waveguides with its high refractive index difference make them attractive for non-linear processes in integrated optics in general, in particular also for a novel class of quantum optical devices. Due to the novelty of the material, where substantial research occurs since only a few years, the experience with LNOI compared to other materials is still quite limited. This makes LNOI a technological challenging material.
We face the challenge and establish a reliable LNOI technology. On a first step we focused on the fabrication of nano-waveguides. We use a dry etching process with the need of etching masks. Hence, we tested different materials like titanium and photo resist on bare lithium niobate to find the optimal etching masks. We demonstrate that photo resist is the best choice to get smooth waveguide sidewalls. After optimization we transferred the fabrication process to the LNOI platform. We show our recent results of in-house fabricated LNOI nano-waveguides.

Q 39.25 Wed 16:30 Empore Lichthof

Towards a heralded single-photon plug-and-play source — •Christian Kiessler[1], Harald Herrmann[1], Hauke Conradi[2], Moritz Kleinert[2], Raimund Ricken[1], Victor Quiring[1], and Christine Silberhorn[1] — [1]Universität Paderborn, Warburger Str. 100, 33098 Paderborn — [2]Fraunhofer HHI Berlin, Einsteinufer 37, 10587 Berlin

To use quantum technologies and its applications practically, integrated quantum devices must be available. Requirements like stability, affordability, miniaturized design, low loss and fiber compatibility are essential for these devices.
Here, we present our first studies on a polymer embedded LiNbO3 crystal, which is designed as an integrated hybrid heralded single-photon source based on spontaneous parametric down-conversion. Due to the large nonlinearity and the possibility of producing low-loss waveguides, periodically poled Ti:LiNbO3 waveguides are used. The final embedding of the LiNbO3 source into a polymer board, which contains further optical components like waveguides, filters and fiber connections, leads to a practicably usable integrated quantum source. At this point we focus on optimizing the LiNbO3 source to reduce the crystal-polymer interface losses, by studying the mode profile and the interface itself. Furthermore, the exact arrangement of the waveguides and the size of the source are examined.

Q 39.26 Wed 16:30 Empore Lichthof

Towards low-loss electrooptical modulators in $LiNbO_3$ for quantum-optics applications — •Felix vom Bruch, Raimund Ricken, Christof Eigner, Harald Herrmann, and Christine Silberhorn — Universität Paderborn, Warburger Str. 100, 33098 Paderborn

The interest in research on quantum technologies and its applications has been steadily increasing during the last decades and an end to this progress is not yet in sight. Many of the most promising applications are based on using light and its properties for quantum information processing and quantum computing. Recent developments in integrated quantum optics provide multi-functional components, such as converters and modulators, allowing an effective reduction of setup footprints accompanied with active tunability and an increase in performance. The usage of the material $LiNbO_3$ enables one to build a variety of passive and active integrated components, based on its large nonlinearity and the possibility of producing high quality low-loss waveguides. In the single photon regime, for example for frequency conversion or modulation, the importance of low-loss devices increases tremendously. Here, we present our latest activities on obtaining low optical losses in active devices, while optimizing the device architecture in terms of modulation performance. At this point we focus on the geometry of the electrodes relative to the crystal orientation. The built devices are envisaged to combine the advantages of conventional low loss bulk modulators with the fast switching of integrated devices, building a foundation of novel programmable quantum networks.

Q 39.27 Wed 16:30 Empore Lichthof

Post-fabrication correction of $LiNbO_3$ modulators via phase-matching temperature tuning — •Fabian Schlue, Marcello Massaro, Matteo Santandrea, Harald Herrmann, and Christine Silberhorn — Universität Paderborn, Warburger Str. 100, 33098 Paderborn

$LiNbO_3$ is commonly used in nowadays telecommunications, because of its high electrooptic (eo) coefficient and the possibly of low loss waveguides, enabling the production of highly integrated and efficient devices. One class of possible devices, making use of the eo effect, are eo modulators. Here, the required driving voltages scale inverse with the used electrode length. Thus, long devices become advantageous in terms of switching speed. However, when fabricating long devices, it becomes increasingly difficult to obtain high homogeneity due to fabrication imperfections. In order to enhance device performance, the necessity of an effective compensation of those imperfections increase. To investigate this a $LiNbO_3$ chip with four cascaded polarization converters in a single device was characterized.
We achieve the compensation by selectively controlling the temperature of the single converter segments. This configuration allows us to systematically tune the overall output by local adjustments of the phase-matching.
Here, we present our results on controlling the array of segments thermally and electrically to optimize the performance of the built device and prove that local control of devices' properties can be a solution to compensating fabrication imperfections.

Q 39.28 Wed 16:30 Empore Lichthof

A low-cost high-finesse scanning cavity for frequency stabilization of a Ba^+ laser cooling system — •Kai Lok Lam, Daniel Hönig, Fabian Thielemann, Pascal Weckesser, Leon Karpa, and Tobias Schätz — Albert-Ludwigs Universität Freiburg

For most applications in atomic- and molecular physics, lasers at several different wavelenghts are needed. High finesse scanning cavities offer the possibility to transfer the stability of a reference laser to a multitude of other lasers simultaneously. In our setup, we currently aim to use a scanning cavity to transfer the stability of a 650nm laser, that is locked to a Doppler-free spectroscopy of idoine, upon a laser operating at 493nm. These two lasers are used for Doppler-cooling Ba^+-ions for our experiments investigating ultracold collisions with Li or Rb atoms.

In this poster, we present our realization of a home-built high-finesse scanning cavity. We show our setup, including the assembly of the cavity itself as well as the signal processing.

Q 39.29 Wed 16:30 Empore Lichthof

Optomechanical gravity sensing based on cavity QED and phonons in Bose-Einstein condensates — •Benjamin Maass and Dennis Rätzel — Humboldt-Universität zu Berlin Institut für Physik AG Theoretische Optik & Photonik

We theoretically investigate the effect of oscillating gravitational fields on phonons, the collective oscillations of a 1D Bose-Einstein condensate (BEC) that is trapped in an optical cavity. As a result of the coupling between the phonons and the cavity modes, the properties of the gravitational field can in principle be inferred from measurements of the light field alone. The applicability of such optomechanical gravity measurement schemes is evaluated.

Q 39.30 Wed 16:30 Empore Lichthof

Bistability in an optomechanically deformable metasurface — •Carol Bibiana Rojas Hurtado[1], Florian Bruns[2], Johannes Dickmann[1], and Stefanie Kroker[1,2] — [1]Physikalisch-Technische Bundesanstalt — [2]Technische Universität Braunschweig

We investigate bistability in silicon nanostructured surface used as an optomechanical system in the telecom wavelength range. The surface consists of two layers of subwavelength gratings with high aspect ratio making it compliant to optical forces. Large optical forces result from employing optical modes with high-quality factors, namely quasi-bound states in the continuum. The two interacting forces are computed with Finite Element Analysis: the induced optical forces from an incoming beam that deform the ridges and the opposing elastic restoring force that brings the system to a new equilibrium position. A graphical method is used to find the solutions at a given input intensity, i.e. one solution for one stable state or three solutions for a bistable condition (one unstable and two stable states). With this method, we can also retrieve the hysteresis curve characteristic of bistability. The stable states correspond to two different values of the optical response of the surface, e.g. a high and low reflectivity of the surface. We investigate the possibility to switch up and down between these two stable states, which is promising for an optomechanically controlled switch operating at low input powers in contrast to the much higher intensities needed in common all-optical switches involving nonlinear materials.

Q 39.31 Wed 16:30 Empore Lichthof

Semiclassical rotation dynamics of quantum rigid rotors — •Birthe Papendell[1], Benjamin A. Stickler[2], and Klaus Hornberger[1] — [1]Faculty of Physics, University of Duisburg Essen, Germany — [2]Quantum Optics and Laser Science, Imperial College London, United Kingdom

Recent progress in the optical manipulation [1,2] of levitated aspherical nanoparticles and the prospect of cooling them into their ro-translational ground state [3] open the door for rotational quantum experiments with nanoscale particles [4]. However, calculating the exact rotational quantum dynamics of such objects is numerically intractable due to the high number of involved rotation states. Here, we present semiclassical approximation methods for planar and linear rigid rotors with several thousand occupied angular momentum states revolving in the presence of an external potential.

[1] T. M. Hoang et al., Phys. Rev. Lett. 117, 123604 (2016)
[2] S. Kuhn et al., Nat. Commun. 8, 1670 (2017)
[3] B. A. Stickler et al., Phys. Rev. A 94, 033818 (2016)
[4] B. A. Stickler et al., New. J. Phys. 20, 122001 (2018)

Q 39.32 Wed 16:30 Empore Lichthof

Novel Optomechanical Coupling Mechanisms in nanostructured Metasurfaces — •Florian Feilong Bruns[1], Carol B. Rojas Hurtado[3], Thomas Siefke[2], and Stefanie Kroker[1,3] — [1]Technische Universität Braunschweig, LENA Laboratory for Emerging Nanometrology, Universitätsplatz 1, 38106 Braunschweig, Germany — [2]Friedrich-Schiller-Universität Jena, Abbe Center of Photonics, Institute of applied Physics, Max-Wien-Platz 1, 07743 Jena, Germany — [3]Physikalisch-Technische Bundesanstalt, Bundesallee 100, 38116 Braunschweig, Germany

Nanostructured metasurfaces with mechanical degrees of freedom provide a highly flexible platform for optomechanical systems. In this work we investigate bilayer metasurfaces as a platform for dispersive and dissipative coupling in the frame of cavity optomechanics. In the upper layer, the metasurface supports bound states in the continuum, optical modes with high field enhancement. Simultaneously, the bottom layer provides a high mechanical susceptibility thus featuring strong optomechanical coupling. We consider two different aspects: We study metasurfaces for tunable intracavity interactions in multimode systems. Furthermore, we show, that the mechanical loss of mechanical oscillators made of high-purity GaAs can be changed by the light intensity. This effect implies a novel optomechanical coupling mechanism that will enrich the dynamics of experiments in cavity optomechanics.

Q 39.33 Wed 16:30 Empore Lichthof

Approaching the motional ground state of a cold nanomechanical oscillator in a hybrid atom-optomechanical system — •Jakob Butlewski[1], Tobias Wagner[1], Philipp Rohse[1], Cody Friesen[2], Felix Klein[1], Roland Wiesendanger[2], Klaus Sengstock[1], Alexander Schwarz[2], and Christoph Becker[1] — [1]Center for Optical Quantum Technologies, University of Hamburg, Luruper Chaussee 149, 22761 Hamburg, Germany — [2]Institute for Nanostructure and Solid State Physics, University of Hamburg, Jungiusstraße 11, 20355 Hamburg, Germany

Hybrid quantum systems pose a promising testbed for quantum theory and may further facilitate the implementation of quantum computation and communication protocols. In our pursuit to realize such a hybrid quantum system we have set up a dedicated experiment to couple ultracold ^{87}Rb atoms to a cryogenic nanomechanical oscillator inside a fiber-cavity. In order to approach the motional ground state of the oscillator we apply active feedback cooling, which is based on a continuous position measurement performed by homodyne detection. Here we report on our progress in cooling the oscillator close to the ground state with a final phonon occupancy of $\langle n \rangle = 3.8$. Furthermore we discuss possible limitations for the lowest achievable temperature in our system as well as solutions to overcome these.

Q 39.34 Wed 16:30 Empore Lichthof

Coupling of a cold nanomechanical oscillator to ultracold atoms in a 3D optical lattice — •Felix Klein[1], Jakob Butlewski[1], Tobias Wagner[1], Philipp Rohse[1], Cody Friesen[2], Roland Wiesendanger[2], Klaus Sengstock[1], Alexander Schwarz[2], and Christoph Becker[1] — [1]Center for Optical Quantum Technologies, University of Hamburg, Luruper Chaussee 149, 22761 Hamburg, Germany — [2]Institute for Nanostructure and Solid State Physics, University of Hamburg, Jungiusstraße 11, 20355 Hamburg, Germany

In recent years hybrid quantum systems became a highly interesting topic as they allow to combine the individual benefits of different quantum systems to overcome the limitations in their respective parts. Therefore, these systems are, among others, promising for future applications in quantum information science. Here we report about coupling a cryogenically cooled nanomechanical trampoline oscillator inside a Fiber Fabry-Pérot Cavity (FFPC) to ultracold atoms in a 3D optical lattice. We characterize the coupling to motional degrees of freedom by loading the atoms into a near-detuned, optical 1D lattice which is formed by back reflection from the oscillator inside the FFPC. Scattering losses due to resonant light are partially compensated by a very deep far-detuned 2D confinement lattice. We observed signatures of resonant coupling in the form of heating the at $\omega_{\mathrm{latt}} = \omega_{\mathrm{m}}$. Coupling the trampoline oscillator to the atoms at varying mode temperature we find clear indications for temperature dependent heating rates.

Q 39.35 Wed 16:30 Empore Lichthof

Levitated opto-mechanics for gravitational wave sensing — •Cristina Matrero Ferrer and Dennis Rätzel — Institut für Physik, Humboldt Universität zu Berlin, Newtonstraße 15, 12489 Berlin

The observation of gravitational waves by the LIGO-Virgo collaboration boosted the interest of the scientific community to the emerging field of gravitational wave astronomy, and also, the interest to find, and hopefully to build, alternative gravitational wave detectors. Interesting alternative options are to use nano-particles levitated in the beamline of an interferometric detector and other advanced opto-mechanical systems. This promises higher precision in different frequency regimes and smaller and cheaper detectors. This work is a theoretical investigation of such opto-mechanical systems as sensors for gravitational waves.

Q 39.36 Wed 16:30 Empore Lichthof

Zerodur based optical benches for microgravity applications — •Jean Pierre Marburger[1], Moritz Mihm[1], Sören Boles[1], André Wenzlawski[1], Ortwin Hellmig[2], Klaus Sengstock[2], Patrick Windpassinger[1], and the MAIUS and BECCAL team[3,4,5,6,7] — [1]Institut für Physik, JGU, Mainz — [2]ILP, UHH, Hamburg — [3]Institut für Physik, HU Berlin, Berlin — [4]FBH, Berlin — [5]IQ & IMS, LUH, Hannover — [6]ZARM, Bremen — [7]Institut für Quantenoptik, Universität Ulm, Ulm

Microgravity environments such as a sounding rocket or a satellite can greatly benefit a number of quantum optics experiments. These experiments often entail a compact and lightweight laser system that can withstand high thermal fluctuations and mechanical stress. To this end, we have developed a technology based on fibre-coupled optical benches made from Zerodur, a glass-ceramic that exhibits a near zero coefficient of thermal expansion, onto which free-space optical components are glued. We have successfully used this toolkit for the creation of a BEC in the scope of the MAIUS-1 sounding rocket mission and will further use it for the upcoming MAIUS-2/3 and the NASA-DLR Bose-Einstein Condensate and Cold Atom Laboratory (BECCAL) mission aboard the ISS. For the latter we have adapted our toolkit, making our system even more compact. Our work is supported by the German Space Agency DLR with funds provided by the Federal Ministry for Economic Affairs and Energy (BMWi) under grant number 50 WP 1433 and 50 WP 1703.

Q 39.37 Wed 16:30 Empore Lichthof

Multi-cell optical memories in warm Cs vapor — •Leon Messner[1,2], Luisa Esguerra Rodriguez[1,2], and Janik Wolters[1,2] — [1]Deutsches Zentrum für Luft- und Raumfahrt e.V. (DLR), Institute of Optical Sensor Systems, Rutherfordstr. 2, 12489 Berlin, Germany. — [2]TU Berlin, Institut für Optik und Atomare Physik, Hardenbergstr. 36, 10623 Berlin, Germany.

The storage of quantum optical pulses in atomic media is considered a key concept in the development of quantum computation and communication techniques. Developing feasable methods for scaling the number of pulses stored, is also an important step in enabling applications such as quantum repeaters [1] and readily available single photon sources [2].

In our experiment we are aiming to map optical excitations to collective atomic states in warm Cs vapor cells with on-demand storage and retrieval. The design is based on an EIT scheme, where a Λ-type atomic system is coupled to free-space control and signal pulses. By deflecting these pulses with acousto-optic modulators prior to entering the atomic media, we can address multiple volumina inside the Cs vapor, thus creating a multi-cell memory [3]. This work is exploring the operational parameters to obtain reproducible optical deflection of the beams for consistent addressing of individual memory cells [4].

[1] Kimble, H., Nature **453**, 1023-1030 (2008)
[2] Nunn, J. et al., PRL **110**, 133601 (2013)
[3] Wolters, J. et al., PRL **119**, 060502 (2017)
[4] Pu, Y. et al., Nat Commun **8**, 15359 (2017)

Q 39.38 Wed 16:30 Empore Lichthof

Quantum Memories suited for Space — •Luisa Esguerra Rodriguez[1,2], Leon Messner[1,2], and Janik Wolters[1,2] — [1]Deutsches Zentrum für Luft- und Raumfahrt e.V. (DLR), Institute of Optical Sensor Systems, Rutherfordstr. 2, 12489 Berlin, Germany. — [2]TU Berlin, Institut für Optik und Atomare Physik, Hardenbergstr. 36, 10623 Berlin, Germany.

Quantum memories are a key element for the realization of quantum repeaters, essential for long-distance quantum communication. Especially for satellite-based quantum networks, alkali metal vapours constitute an excellent storage platform. Moreover, compound quantum systems combining said memories with single photon sources open the path for applications in quantum simulation and computing. The presented project explores a quantum memory implemented in a warm Cesium vapour cell using electromagnetically induced transparency (EIT) on the D1-line, similar to [1]. Light storage, first for attenuated laser pulses and later at the single photon limit, will be investigated. For the latter, single photons from a semiconductor quantum dot source, or a parametric down-conversion source will be used [2]-[4]. Furthermore, noise and efficiency limits of on-demand storage and retrieval will be studied, and optimized. Numerical simulations for optimal storage will be performed.

[1] J. Wolters et al., PRL **119**, 060502 (2017)
[2] J. Wolters et al., arXiv:1908.00590v1 (2019)
[3] A. Ahlrichs, O. Benson, Appl. Phys. Lett. **108,** 021111 (2016)
[4] T. Kroh et al., Sci Rep 9, 13728 (2019)

Q 39.39 Wed 16:30 Empore Lichthof

Ensuring the privacy of random numbers generated by quantum processes — •Johannes Seiler[1], Thomas Strohm[2], and Wolfgang P. Schleich[1,3] — [1]Institut für Quantenphysik and Center for Integrated Quantum Science and Technology (IQ ST), Universität Ulm, D-89069 Ulm,Germany — [2]Corporate Research, Robert Bosch GmbH, D-71272 Renningen, Germany — [3]Institute of Quantum Technologies, German Aerospace Center (DLR), Söflinger Str. 100, D-89077 Ulm, Germany

An important advantage of a quantum random number generator (QRNG), compared to its classical counterparts, is that quantum mechanics ensures that the generated random numbers are, even in principle, not predictable by an attacker. Unfortunately, real life implementations of QRNGs usually suffer from imperfections that theoretically open the door for an attacker to get at least partial information about the generated numbers. However, if we know how much information an attacker can have maximally gained, postprocessing of the raw data allows to secure the privacy of the random numbers. The task is therefore to obtain an upper bound on this information. We discuss this problem for a realistic QRNG by modeling the random number generator and its environment. As a result, we prove that the information accessible to the attacker crucially depends on the entanglement between the state of the QRNG and its environment. Moreover, we take into account the effects of imperfect measurements. Finally, we provide a scheme that allows us to calculate an upper bound for the accessible information, without any further knowledge of the state.

Q 39.40 Wed 16:30 Empore Lichthof

Efficient single-photon collection for long-distance entanglement of atoms — •Matthias Seubert[1], Robert Garthoff[1], Tim van Leent[1], Kai Redeker[1], Derya Taray[1], Wei Zhang[1], Wenjamin Rosenfeld[1,2], and Harald Weinfurter[1,2] — [1]Fakultät für Physik, Ludwig-Maximilians-Universität, Munich, Germany — [2]Max-Planck-Institut für Quantenoptik, Garching, Germany

An essential role in future quantum communication applications, such as quantum repeaters and quantum networks, will be entanglement between quantum memories seperated over large distances. Currently, the entanglement generation rate of single atoms in schemes based on entanglement swapping is limited by the collection efficiency of emitted photons. To overcome this limit, new optics for optimizing the collection efficiency of single photons, emitted by an optically trapped Rb-87 atom was designed. Here we describe the implementation of this new custom designed high-NA microscope objective and its characterization. We obtained an improvement of the photon collection efficiency by a factor of 2.5, which will increase the atom-atom entanglement rate by a factor of 6 with regard to [1]. Furthermore, simulations show that the coupling efficiency of photons into single-mode-fibres can be further increased by 5% using a custom designed fiber collimator. The improved collection efficiency was mendatory to compensate the loss in frequency conversion such that we could demonstrate long distance entaglement between an atom and a photon over 20 km of fiber [2].

[1] W. Rosenfeld, Phys. Rev. Lett. **119**, 010402 (2017)
[2] T. van Leent, arXiv:1909.01006 (2019)

Q 39.41 Wed 16:30 Empore Lichthof

Entanglement conditions for multipartite quantum key distribution — •Giacomo Carrara, Gláucia Murta, and Dagmar Bruss — Institut für Theoretische Physik III, Heinrich-Heine-Universität Düsseldorf, Universitätsstr. 1, D-40225 Düsseldorf, Germany

Entanglement is an important resource in quantum cryptography and it is known to be necessary to guarantee security in a bipartite quantum key distribution scenario. It is thus interesting to move to the more complex multipartite scenario, where different classes of entanglement can be defined. In particular we will focus on protocols that utilize a shared multipartite state to generate, each round of the protocol, a common bit of raw key shared among all the parties. Most of the multipartite quantum key distribution protocols of this type proposed so far make use of the Greenberger-Horne- Zeilinger (GHZ) state, or some other genuine multipartite entangled state. Here we ask the question whether genuine multipartite entanglement is necessary to achieve secure multipartite conference key agreement or if biseparable states can also be used in protocols based on multipartite states.

Q 39.42 Wed 16:30 Empore Lichthof

Modification of a Continuous Variable Quantum Authentication Protocol with Physical Unclonable Keys — •Yannick Deller[1], Georgios M. Nikolopoulos[1,2], and Gernot Alber[1] — [1]TU Darmstadt, Darmstadt, Germany — [2]Institute for Electronic Structure & Laser, FORTH, Heraklion, Greece

Entity authentication is an important cryptographic primitive with widespread applications. Entity authentication protocols (EAPs), which rely on physical unclonable keys (PUKs) and involve quantum challenges [1,2], promise a high level of security against classical and quantum adversaries. PUKs are disordered physical objects which are considered to be hard to clone or to simulate. Recently, Nikolopoulos and Diamanti proposed a quantum-optical continuous-variable EAP [2], where the PUK is materialised by a random multiple-scattering medium, while the challenges and the responses are coherent states of light. So far, the security of this protocol has been analysed in the framework of intercept-resend cheating strategies. We discuss the security of the protocol against an emulation attack, which relies on the use of linear quantum-optical chips. It is shown that the protocol of Ref. [2], in its simplest form, is not secure against such a type of attack. Moreover, we discuss possible straightforward modifications of the protocol, so that to prevent this attack, and analyse how the modifications impact the security of the protocol against intercept-resend cheating strategies.

[1] Goorden et al., Optica, Volume 1, 421 (2014)
[2] Nikolopoulos and Diamanti, Sci. Rep., Volume 7, 46047 (2017)

Q 39.43 Wed 16:30 Empore Lichthof

Development of a QKD satellite ground station — •Bastian Hacker[1], Conrad Rössler[1,2], Kevin Günthner[1,2], Ömer Bayraktar[1,2], Jonas Pudelko[1,2], Kevin Jaksch[1,2], Imran Khan[1,2], Gerd Leuchs[1,2], and Christoph Marquardt[1,2] — [1]Max Planck Institute for the Science of Light, Staudtstraße 2, 91058 Erlangen, Germany — [2]Friedrich Alexander University Erlangen-Nuremberg, Staudtstraße 7/B2, 91058 Erlangen, Germany

Quantum Key Distribution (QKD) holds the promise of enabling provable secure communication. In today's efforts based on optical transmission, the challenge is to handle significant transmission losses. Complementary to fiber-based QKD with trusted nodes or quantum repeaters, satellite-based QKD systems [1] for large-distance communication are being developed. To this end, a European quantum satellite will be implemented, capable of secure quantum key exchange with a ground station. We present the project status and highlight some of the technical requirements to operate such a system under real-world conditions.

[1] I. Khan et al., Opt. Photonics News 29(2), 26-33 (2018)

Q 39.44 Wed 16:30 Empore Lichthof

Bounding Secret Key Rates for a Real World QKD Implementation — •Daniel Derr, Alexander Sauer, and Gernot Alber — Institut für Angewandte Physik, Technische Universität Darmstadt

In general, the secrecy of entanglement based quantum key distribution (QKD) can be guaranteed by checking for the violation of some Bell inequality. The amount of cryptographic key bits, which can be extracted from given measurement results, depends on the strength of this violation. To compute a secret key rate, the chosen protocol and the capabilities of a potential attacker have to be taken into account. We analyze the achievable key rate of a QKD setup based on phase-time coding, which is being developed experimentally at TU Darmstadt. To this end, we take into account the specific properties of that setup, which may give a potential adversary full access over the quantum channel.

Q 39.45 Wed 16:30 Empore Lichthof

Photon Generation by Spontaneous Parametric Down Conversion for Quantum Key Distribution — •Julian Nauth, Alexander Sauer, Erik Fitzke, Gernot Alber, and Thomas Walther — Institut für Angewandte Physik, Technische Universität Darmstadt

We consider a source which generates entangled photons by spontaneous parametric down conversion (SPDC). After passing through a setup, the photons are measured by two parties to generate a secret key via a phase-time coding based quantum key distribution (QKD) protocol. As the requirements for the experimental components are highly demanding in this QKD setup, we aim to characterize the influence of imperfect devices, such that the resulting errors do not have to be attributed to a potential eavesdropper. We simulate the setup by modeling the states of the system as multimode Gaussian states which are transformed by each component of the setup. With this, SPDC and subsequent frequency- and polarization-dependent effects are modeled. The simulation yields the correlations of detection events for the parties at different times. We compare our calculations to experimental results and analyze the influence of different device imperfections on the correlations.

Q 39.46 Wed 16:30 Empore Lichthof

Towards quantum teleportation in space and frequency using a comb of squeezed vacuum — •Dennis Wilken[1,2,3], Jonas Junker[1,2,3], and Michèle Heurs[1,2,3,4] — [1]Leibniz Universität Hannover, Institut für Gravitationsphysik, Deutschland — [2]Max Planck Institut für Gravitationsphysik, Deutschland — [3]QuantumFrontiers — [4]PhoenixD

Sources of squeezed vacuum are now routinely implemented in gravitational wave detectors. These so-called "squeezers" are based on a parametric down-conversion process generating pairs of entangled photons at frequencies $\pm\Omega$ with respect to the laser frequency. We intend to use this entanglement by frequency-dependently separating these photons using an unbalanced Mach-Zehnder interferometer or detuned cavities. We are designing different experiments, such as a measurement-induced entanglement and entanglement swapping, to demonstrate quantum teleportation in space and frequency. This could enable frequency multiplexing in continuous variable quantum communication.

We have set up an optical parametric oscillator cavity that runs below threshold to generate squeezed states of vacuum. It has a comparably high roundtrip length of 1.5 m to generate a squeezing comb with a "teeth separation" of only 200 MHz. We were able to generate and stably lock 9 dB of squeezing. We have developed a low-noise and high-speed homodyne-detector that provides more than 10 dB of clearance between shot noise and electronic noise up to 3 GHz. We will present the current status of the experiment and the next steps.

Q 39.47 Wed 16:30 Empore Lichthof

Microwave antenna design for fiber-based microcavities — •Jonas Grammel, Maximilian Pallmann, and David Hunger — Physikalisches Institut (PHI), Karlsruher Institut für Technologie, Wolfgang-Gaede-Str.1, 76131 Karlsruhe, Germany

The realization of a quantum repeater is a central subject of current research in the field of optical quantum technologies. One promising platform to implement an efficient spin-photon interface - which is the basic building block of a quantum repeater - is based on NV centers in diamond coupled to tunable, fiber-based microcavities [1,2,3]. Asides to excellent optical cavity-emitter coupling and coherent optical control, one also requires direct control of the spin degree of freedom via microwave radiation [4]. Therefore, we develop a microscopic microwave antenna which is directly integrated in the fiber cavity assembly in a way that isolates the thermal impact of the antenna from the diamond sample [5]. We will describe the current state of the efforts to use this antenna to measure optically detected magnetic resonance and drive arbitrary pulse sequences.

[1] D. Hunger et al., New J. Phys. 12, 065038 (2010) [2] H. Kaupp et al., Phys. Rev. Appl. 6, 054010 (2016) [3] D. Riedel et al., Phys. Rev. X 7, 031040 (2017) [4] S. Bogdanovic et al., APL Photonics 2, 126101 (2017) [5] I. Fedotov et al., Sci Rep 4, 5362 (2015)

Q 39.48 Wed 16:30 Empore Lichthof

Entanglement for non-adaptive measurement-based quantum computation — •Bülent Demirel[1], Weikai Weng[1], Christopher Thalacker[1], Akshey Kumar[1], Matty Hoban[2], and Stefanie Barz[1] — [1]Universität Stuttgart — [2]Goldsmiths, University of London

Multipartite entangled states are useful for applications such as quantum networking and computing but also enable intriguing experiments on fundamental questions of quantum physics. Today*s quantum technologies are based on the properties of large ensembles of particles. We show the generation of 4-photon entanglement and test inequalities that correspond to computational games for computing a Boolean function of three bits distributed across four parties - this is all in the non-adaptive measurement-based quantum computation (MBQC) model.*Our inequalities compare quantum with classical where we don*t allow any communication for the classical model or where some limited communication, for a circuit of depth 1, is allowed. We experimentally verify a violation of the inequalities as this demonstrates that quantum can outperform a classical communication circuit.

Q 39.49 Wed 16:30 Empore Lichthof

Building the necessary setup infrastructure for spin-photon entanglement and quantum repeaters with colour centers in silicon carbide. — •Izel Gediz, Naoya Morioka, Matthias Niethammer, Charles Babin, Di Liu, Erik Hesselmeier, Roland Nagy, Durga Dasari, Florian Kaiser, and Jörg Wrachtrup — 3rd Institute of Physics, University of Stuttgart and IQST, Stuttgart, Germany

Concerning the scalability of quantum information and networking applications, colour centers in silicon carbide (SiC) have proven to be promising candidates. The successful implementation of a quantum repeater requires a high-quality spin-photon entanglement interface.Our recent work on silicon vacancy centres in SiC showed spin-controlled indistinguishable and distinguishable photon emission through Hong-Ou-Mandel interference experiments. Here, I will show our current work on developing the necessary setup infrastructure for realising spin-photon entanglement generation. To ensure transform limited photon emission over long times, a high-finesse filter cavity was developed. A cross-polarised sub-nanosecond-pulsed excitation-emission setup was implemented to efficiently reject laser noise by more than 7 orders of magnitude. Finally, an unbalanced fibre interferometer was set up to analyse photonic time-bin quantum states. For all systems, active monitoring and stabilisation feedback is provided through a Python computer code. Our successful setup implementation paves the way for future spin-photon entanglement experiments with colour centres in an industrial semiconductor platform.

Q 39.50 Wed 16:30 Empore Lichthof

Certified Randomness from Bell's Theorem and Dimension Witness — •Xing Chen[1], Ilja Gerhardt[1], Jörg Wrachtrup[1,2], Robert Garthoff[3,4], Kai Redeker[3,4], Wenjamin Rosenfeld[3,4], and Harald Weinfurter[3,4] — [1]3. Institute of Physics, University of Stuttgart and Institute for Quantum Science and Technology IQST, Pfaffenwaldring 57, D-70569 Stuttgart, Germany — [2]Max Planck Institute for Solid State Research, Heisenbergstraße 1, D-70569 Stuttgart, Germany — [3]Fakultät für Physik, Ludwig-Maximilians-Universität München, D-80799 München, Germany — [4]Max-Planck Institut für Quantenoptik, D-85748 Garching, Germany

Device-independent (DI) randomness can be certified from experimental data which violates the CHSH inequality. The certification procedure in previous studies cannot fully extract the DI randomness by an analytical formula. We solve this problem by developing an analytical upper bound for the joint outcome probability $p(ab|xy)$. Compared to the formula in S. Pironio et al. [Nature (London) 464,1021(2010)], the lower the violation S value is, the relative more DI randomness can be certified by our analytical bound. Under less secure semi-device-independent (SDI) conditions, which use dimension witnesses [1], substantial more randomness can be extracted than in the device-independent cases. We furthermore apply our models for the loop-hole free Bell test experiment [2], the results show that nearly half of the experimental events can be certified as SDI randomness.

[1] J. Bowles,et al.,PRL.112.14(2014):140407.
[2] W. Rosenfeld,et al.,PRL.119.1(2017):010402.

Q 39.51 Wed 16:30 Empore Lichthof

Certified Randomness from Bell's Theorem and Dimension Witness — •Xing Chen[1], Ilja Gerhardt[1], Jörg Wrachtrup[1,2], Robert Garthoff[3,4], Kai Redeker[3,4], Wenjamin Rosenfeld[3,4], and Harald Weinfurter[3,4] — [1]3. Institute of Physics, University of Stuttgart and Institute for Quantum Science and Technology IQST, Pfaffenwaldring 57, D-70569 Stuttgart, Germany — [2]Max Planck Institute for Solid State Research, Heisenbergstraße 1, D-70569 Stuttgart, Germany — [3]Fakultät für Physik, Ludwig-Maximilians-Universität München, D-80799 München, Germany — [4]Max-Planck Institut für Quantenoptik, D-85748 Garching, Germany

Device-independent (DI) randomness can be certified from experimental data which violates the CHSH inequality. The certification procedure in previous studies cannot fully extract the DI randomness by an analytical formula. We solve this problem by developing an analytical upper bound for the joint outcome probability $p(ab|xy)$. Compared to the formula in S. Pironio *et al.* [Nature (London) 464,1021(2010)], the lower the violation S value is, the relative more DI randomness can be certified by our analytical bound. Under less secure semi-device-independent (SDI) conditions, which use dimension witnesses [1], substantial more randomness can be extracted than in the device-independent cases. We furthermore apply our models for the loop-hole free Bell test experiment [2], the results show that nearly half of the experimental events can be certified as SDI randomness.

[1] J. Bowles, *et al.*, PRL.112.14 (2014):140407.
[2] W. Rosenfeld, *et al.*, PRL.119.1 (2017):010402.

Q 39.52 Wed 16:30 Empore Lichthof

Monte Carlo simulations for determining the volume ratio separable to entangled states in a two-qubit system — •Héctor José Moreno[1], Jósef Zsolt Bernád[1,2], and Gernot Alber[1] — [1]Institut für Angewandte Physik, Technische Universität Darmstadt, D-64289 Darmstadt, Germany — [2]Department of Physics, University of Malta, Msida MSD 2080, Malta

In this work, we investigate the question of how many separable states are in the set of all quantum states. We focus on a two-qubit composite system and its Fano type of parametrization. The number of free parameters is 15 and due to the chosen parametrization, we are able to characterize general self-adjoint matrices with trace one and eigenvalues between minus one and one. Thus, the first task is to find all positive matrices, i.e., the density matrices, which can be realized with the help of the Newton identities. These identities lead to three inequalities and these analytical results are investigated with the help of Monte Carlo simulations. Then, the separability of the states is determined using the Peres-Horodecki criterion. While many previous approaches have considered this question, here we try a different numerical and analytical approach for estimating the volume ratio of separable to entangled states. Our combined analytical and numerical approaches can also be extended to a qubit- qutrit system, where the Peres-Horodecki criterion still holds.

Q 39.53 Wed 16:30 Empore Lichthof

Test of a time-bin entanglement-based QKD system in a commercial optical link — •Jakob Kaltwasser, Erik Fitzke, Oleg Nikiforov, Maximilian Tippmann, and Thomas Walther — AG Laser und Quantenoptik, Institut für Angewandte Physik, Technische Universität Darmstadt, Schlossgartenstraße 7, 64289 Darmstadt, Germany

Quantum Key Distribution has significant relevance in further development of cryptographic data exchange and key distribution systems. It offers new aspects of enhancement in security for key distribution compared to classical protocols. We are working on a time-bin entanglement-based system for quantum key distribution which is developed and tested in a commercial telecommunication environment. This non-laboratory environment has challenging aspects especially with respect to a portable and compact system as well as a high instability of temperature and noise background and its effects on the system. Consequently we developed a compact optical-fiber-based system for the photon-pair source. In this contribution we discuss the recent progress of our experiment and present our latest results.

Q 39.54 Wed 16:30 Empore Lichthof

A quantum network node with crossed fiber cavities — •Gianvito Chiarella[1], Manuel Brekenfeld[1], Dominik Niemietz[1], Pau Farrera[1], Joseph D. Christesen[1,2], and Gerhard Rempe[1] — [1]MPQ, Hans-Kopfermann-Str. 1, 85748 Garching, Germany — [2]NIST, Boulder, Colorado 80305, USA

Single atoms embedded in optical cavities have been proven to be a clean and fruitful experimental platform for the study of quantum information processing. In recent years, limits on the reduction of the cavity mode volume imposed by traditional manufacturing processes of the cavity mirrors have been overcome with the introduction of Fabry-Perot fiber cavites (FFPCs) [1]. Beside small mode volumes and larger coupling rates, FFPCs also allow for new geometries due to their smaller dimensions that enables the increase of the number of independent cavity modes the atom can couple to. We have set up a new experiment with single neutral atoms trapped at the center of two crossed FFPCs. Exploiting the possibilities provided by the new system, we have realized a quantum network node that couples to two spatially and spectrally distinct quantum channels. The node functions as a passive, heralded and high-fidelity quantum memory that requires neither amplitude- and phase-critical control fields [2] nor error-prone feedback loops [3] and is thus excellently suited for the realization of large-scale quantum networks and quantum repeaters.

[1] Hunger et al., New J. Phys. **12**, 065038 (2010)
[2] Specht et al., Nature **473**, 190 (2011)
[3] Kalb et al., Phys. Rev. Lett. **114**, 220501 (2015)

Q 39.55 Wed 16:30 Empore Lichthof

Quantum Memories based on Adiabatic Transfer and Beyond — •Tom Schmit, Luigi Giannelli, and Giovanna Morigi — Theoretische Physik, Universität des Saarlandes, 66123 Saarbrücken, Germany

Quantum memories are the storage units of a quantum network [1]. The transfer of the qubit state to the memory can be accomplished by different types of protocols. Typically, protocols based on adiabatic dynamics are preferrable due to their robustness against moderate fluctuations of experimental parameters, on the other hand they require long-transfer times. In this work we analyse theoretically the efficiency of adiabatic storage of single photons [2] in quantum memories based on (i) a single atom inside an optical resonator and (ii) a solid-state medium. We discuss the efficiency of protocols based on adiabatic dynamics [3,4] when applied in the non-adiabatic regime. We finally extend these protocols by including pulses determined via optimal control theory and analyse their efficiency.

[1] H. J. Kimble, Nature **453**, 1023 (2008).
[2] N. Sangouard and H. Zbinden, Jour. of Mod. Opt., **59:17**, 1458-1464 (2012).
[3] M. Fleischhauer, and M. D. Lukin, Phys. Rev. A, **65**, 022314 (2002).
[4] A. V. Gorshkov, A. André, M. D. Lukin, and A. S. Sørensen, Phys. Rev. A, **76**, 033804 (2007).

Q 39.56 Wed 16:30 Empore Lichthof

A Versatile High-Speed Continuous-Variable Quantum Communication System — Imran Khan[1,2], •Stefan Richter[1,2], Kevin Jaksch[1,2], Kevin Guenthner[1,2], Ömer Bayraktar[1,2], Emanuel Eichhammer[1,2], Bastian Hacker[1,2], Birgit Stiller[1,2], Gerd Leuchs[1,2], and Christoph Marquardt[1,2] — [1]Max-Planck-Institute for the Science of Light, Erlangen, Germany — [2]Friedrich-Alexander-Universität Erlangen-Nürnberg, Erlangen, Germany

Over the last years, the quantum information processing group at MPL has developed a fiber-based continuous-variable quantum communication system for deployment alongside and compatible with existing telecom infrastructure. In this work, we present our technological advancements as well as the role of this fiber-based quantum communication system within national and EU quantum flagship projects. The projects covered are: HQS (BMBF), QuNET (BMBF), CiViQ (EU Quantum Flagship) and the European quantum key distribution testbed OPENQKD (EU H2020).

Q 39.57 Wed 16:30 Empore Lichthof

Magnetic interactions in nonequilibrium atom-surface dispersion forces — •Simon Hermann[1], Kurt Busch[1,2], and Francesco Intravaia[1] — [1]Humboldt- Universität zu Berlin, Institut für Physik, AG Theoretische Optik & Photonik, Newtonstr. 15, 12489 Berlin, Germany — [2]Max Born Institute for Nonlinear Optics and Short Pulse Spectroscopy, Max-Born-Str. 2A, 12489 Berlin, Germany

Driving a microscopic object above a planar medium induces a force opposing the direction of motion even if both the object and the material are non-magnetic and electrically neutral. The interaction stems from the fluctuations within the microscopic object and the medium and occurs even if the temperature goes to zero, rendering the effect a purely quantum phenomenon. This fluctuation-induced interaction heavily relies on long-time correlations making it an excellent example of a non-Markovian nonequilibrium phenomenon [1]. Due to the mathematical complexity of the problem, most of the earlier descriptions focused on the electric contribution to the interaction. Here, we present a more complete treatment that also takes into account the contribution arising from the nonequilibrium magnetic fluctuations of the system.

[1] F. Intravaia, R. O. Behunin, C. Henkel, K. Busch and D.A.R. Dalvit
Non-Markovianity in atom-surface dispersion forces Phys. Rev. A **94** 042114 (2016).

Q 39.58 Wed 16:30 Empore Lichthof

Probing the Quantum Vacuum with High-Intensity Laser Fields — Ricardo R.Q.P.T. Oude Weernink[1,2], •Leonhard Klar[1,2], Felix Karbstein[1,2], and Holger Gies[1,2] — [1]Theoretisch-Physikalisches Institut, Friedrich-Schiller-Universität Jena, 07743 Jena, Germany — [2]Helmholtz-Institut Jena, 07743 Jena, Germany

From the perspective of quantum field theory vacuum is not the absence of everything but characterized by the omnipresence of quantum vacuum fluctuations. In contrast to classical vacuum it is described by virtual particle-antiparticle pairs being created and annihilated on extremely short time and length scales. The theory of quantum electrodynamics (QED) predicts non-linear effective interactions between electromagnetic fields mediated by such vacuum fluctuations. These effects however are yet to be measured directly.

One example of QED vacuum non-linearity is the process of photon-photon scattering. In order to make this process experimentally accessible we suggest two different approaches. The first collides several tightly focused fundamental Gaussian laser beams. Using frequency doubling and a special geometry we generate a narrow high-intensity scattering center allowing us to obtain signal photons discernible from the background of the driving laser beams. In the second approach, we limit ourselves to two counter-propagating pulses. This time however both beams are considered to be arbitrary Hermite-Gaussian modes. This results in interesting field configurations which are examined for their potential to induce signal photons distinguishable from the background with finite impact parameter.

Q 39.59 Wed 16:30 Empore Lichthof

State transfer from a single photon to a quantum emitter and quantum cloning — •Marvin Gajewski, Thorsten Haase, and Gernot Alber — Institut für Angewandte Physik, Technische Universität Darmstadt, Deutschland

Achieving optimal quantum state transfer from a single photon to a quantum emitter is a highly desired task in quantum information processing. This enables conversion from flying into stationary qubits and enhances quantum computation and communication, in particular scalable communication networks. A scheme achieving this task was presented in [1]. It enables an almost perfect transfer of the information stored in the polarization degrees of freedom of a single photon onto a suitable level scheme of a single quantum emitter by exploiting the dissipation induced by spontaneous emission of photons. It has been shown that under certain assumptions, such as orthogonality of the involved photonic reservoirs, a particular balancing of the relevant photonic spontaneous decay rates is necessary.

In this contribution we generalize these investigations by dropping some of these previous assumptions, such as the orthogonality of the coupling and background modes involved. Within this more general scenario it is explored to which extent imperfect quantum cloning is possible due to information leakage into the state of the spontaneously emitted photon.

Q 39.60 Wed 16:30 Empore Lichthof

Numerical calculation of Casimir interactions in complex geometries — •Bettina Beverungen[1], Philip Kristensen[1], Francesco Intravaia[1], and Kurt Busch[1,2] — [1]Humboldt-Universität zu Berlin, Institut für Physik, AG Theoretische Optik & Photonik, Newtonstr. 15, 12489 Berlin, Germany — [2]Max Born Institute for Nonlinear Optics and Short Pulse Spectroscopy, Max-Born-Str. 2A, 12489 Berlin, Germany

The Casimir effect is responsible for a force between nonmagnetic, electrically neutral objects arising from the quantum fluctuations of the electromagnetic field. This interaction has received increasing attention from both theoretical and experimental side, in particular for its relevance in the design of small-scale devices such as nano- or micro electro-mechanical systems and atom-chips. To fully explore the space of possible designs, it is imperative to develop methods to evaluate Casimir forces for non-trivial geometries and materials allowing for high flexibility and precision. Here, we discuss a time-domain finite-element-based numerical scheme employing the discontinuous Galerkin time-domain (DGTD) method. This calculation method enables high-accuracy evaluation of Casimir- and Casimir-Polder forces in complex geometries and for a broad class of material models.

Q 39.61 Wed 16:30 Empore Lichthof

Interplay between collective Lamb shift and hyperfine splitting in resonant x-ray scattering — •Petar Andrejić, Xiangjin Kong, and Adriana Pálffy — Max Planck Institute for Nuclear Physics, 69117 Heidelberg,Germany

In an ensemble of identical atoms, cooperative effects like superradiance may alter the decay rates and the transition energies may be shifted from the single-atom value by the so-called collective Lamb shift. While such effects in ensembles of two-level systems are well understood, realistic multi-level systems are more difficult to handle. Mössbauer nuclei in x-ray thin-film cavities are a clean quantum optical system in which the collective Lamb shift has been observed [1].

Here, we present a quantitative study of ensembles of ^{57}Fe nuclei which considers for the first time the action of both an external magnetic field and an intrinsic quadrupole splitting. We show that a collective contribution to the level shifts appears that can amount to sizable deviations from the single-atom hyperfine splitting due to the interplay with the collective Lamb shift. We discuss possible experimental evidence of deviations in the radiation spectrum compared to the case of single-nucleus magnetic-field-induced splitting [2].

[1] R. Röhlsberger *et al.*, Science 328, 1248 (2010).
[2] X. Kong and A. Pálffy, Phys. Rev. A 96, 033819 (2017).