Q 62: Poster: Quantum Optics and Photonics V

Time: Thursday 16:15–18:15 Location: Redoutensaal

Q 62.1 Thu 16:15 Redoutensaal

Creating Homogeneous Two-Dimensional Fermi Gases — •Fynn Förger, Lennart Sobirey, Niclas Luick, Klaus Hueck, Jonas Siegl, Thomas Lompe, and Henning Moritz — Institut fuer Laserphysik, Universitaet Hamburg, Luruper Chaussee 149, 22761 Hamburg, Germany

In this poster we present the creation and investigation of homogeneous two-dimensional Fermi gases. These gases are well suited to study the intriguing interplay of reduced dimensionality and strong interactions.

To create a two-dimensional system we load our atoms into a strong confining 1D optical lattice. This freezes out any motional degrees of freedom in the third direction. To load 2D Fermi gases both in single and double layer configuration, we developed a method to detect the occupation of the different layers in a single shot measurement.

Homogeneity is achieved by confining the atoms in a box potential in the remaining two directions, which is formed by a repulsive ring-shaped potential created with an optical setup employing three axicons.

We demonstrate how the in plane momentum distributions can be obtained using matter wave focusing and how spin removal can mitigate interaction effects during time of flight. Finally, we report on a novel method to calibrate high intensity absorption imaging to high precision using relative measurements of the momentum transferred to the atoms by the imaging light.

Q 62.2 Thu 16:15 Redoutensaal

Exploring the doped Fermi-Hubbard model in low dimensions — •Jayadev Vijayan[1], Timon Hilker[1], Guillaume Salomon[1], Joannis Koepsell[1], Michael Höse[1], Immanuel Bloch[1,2], and Christian Gross[1] — [1]Max-Planck-Institute für Quantenoptik, Garching — [2]Fakultät für Physik, Ludwig- Maximilians-Universität, München

We use ultracold fermionic lithium atoms in an optical lattice to realize synthetic one dimensional Fermi-Hubbard chains. Using a quantum gas microscope that can resolve local spin and density, we study emerging antiferromagnetic correlations as a function of doping and magnetization. We see signatures of spin-charge separation in the one dimensional chains by using three point correlation functions, opening the route towards a direct measurement of the complex correlations arising in two dimensions. We further observe the change of the wave vector of the spin correlations as a function of density and magnetization, which can be well described by Luttinger-liquid theory. Finally we report on ongoing studies of the system in the crossover from one to two dimensions.

Q 62.3 Thu 16:15 Redoutensaal

Detecting correlations in deterministically prepared quantum states with single-atom imaging — •Andrea Bergschneider, Vincent M. Klinkhamer, Jan Hendrik W. Becher, Ralf Klemt, Gerhard Zürn, Philipp M. Preiss, and Selim Jochim — Physikalisches Institut der Universität Heidelberg

We deterministically prepare correlated quantum states consisting of few fermions in a double-well potential. A newly developed imaging scheme for fermionic Lithium allows us to detect these correlations on a single-atom level and with spin resolution.

The detection method uses fluorescence imaging at high magnetic fields where the optical transitions for the used hyperfine states are almost closed. With a high-resolution objective we detect about 20 scattered photons per atom on an EMCCD camera. This is sufficient to identify and locate single atoms. We can apply this scheme insitu or after an expansion in time-of-flight and additionally resolve the spin by subsequently adressing the different hyperfine states.

Using this, we measure the two-particle momentum correlations and thereby probe the spatial symmetry of the two-particle wavefunction. Combining momentum and insitu information, we determine a witness for mode and particle entanglement present in the system. The high contrast and the scalability of our detection technique will allow us to go beyond measuring two-particle correlations and characterize many-body quantum states.

Q 62.4 Thu 16:15 Redoutensaal

Correlations of strongly attractive few-fermion systems — •Philipp M. Preiss, Vincent Klinkhamer, Ralf Klemt, Andrea Bergschneider, Jan Hendrik Becher, Gerhard Zürn, and Selim Jochim — Physikalisches Institut, Universität Heidelberg

Strongly coupled quantum systems are characterized by the correlations between their constituents. We prepare systems with strong attractive interactions containing few 6Li atoms in an optical microtrap. We release the atoms from the trap and measure the positions of the atoms with a spin-resolved single-atom sensitive imaging method after time-of-flight. From these positions, we construct the two-body correlation functions.

Our measurements are ideally suited to study the effects of interactions and quantum statistics in few-particle systems. The measured correlation functions can give access to the microscopic properties of fermionic quantum states and can be used to explore the few-body limit of hydrodynamics or to detect pairing phenomena in the BEC-BCS crossover.

Q 62.5 Thu 16:15 Redoutensaal

Towards a lithium quantum gas microscope for small quantum systems — •Andreas Kerkmann, Michael Hagemann, Mathis Fischer, Benno Rem, Christof Weitenberg, and Klaus Sengstock — Institut für Laserphysik, Hamburg, Germany

We are setting up a new quantum gas microscope for the detection of degenerate samples of ^{6}Li/ ^{7}Li atoms to study strong correlations in small quantum systems. Our design consists of a compact 2D-/ 3D-MOT loading scheme and an all-optical approach for the preparation of degenerate samples. In our poster, we provide information about the details of the design and the current status of the experiment.

Q 62.6 Thu 16:15 Redoutensaal

An experiment for the study of small Hubbard models with rapid repetition rate — •Martin Schlederer, Phillip Wieburg, Alexandra Mozdzen, Thomas Lompe, and Henning Moritz — Institut für Laserphysik, Universität Hamburg, Hamburg, Deutschland

Investigating the Fermi-Hubbard model with cold atoms is typically done by evaporatively cooling an ultracold Fermi gas and loading it into a large optical lattice. In contrast, we plan to assemble small Fermi-Hubbard type systems site by site using optical microtraps. Each microtrap will contain a single atom cooled to the vibrational ground state by Raman-sideband cooling [1]. This technique combines fast experimental cycle times with single site addressability and detection and will allow to study the fundamental processes governing the Fermi-Hubbard model in a bottom-up approach.

The poster will present the current status of the experiment: We trap 40K atoms in a magneto-optical trap and cool them to sub-Doppler temperatures using a gray molasses . After magnetic transport to the science region they are loaded in optical lattices where in the next step Raman sideband cooling will be investigated. In order to load the atoms into flexible configurations of microtraps and to manipulate them individually, we will use two high resolution microscopes objectives located inside the vacuum chamber.

[1] A.M. Kaufman et al., Physical Review X 2, 041014 (2012).

Q 62.7 Thu 16:15 Redoutensaal

Coherent Manipulation of Spin Correlations in the Hubbard Model — •Nicola Wurz[1], Chun Fai Chan[1], Marcell Gall[1], Jan Henning Drewes[1], Eugenio Cocchi[1,2], Luke Alexander Miller[1,2], Daniel Pertot[1], Ferdinand Brennecke[1], and Michael Köhl[1] — [1]Physikalisches Institut, University of Bonn, Germany — [2]Cavendish Laboratory, University of Cambridge, United Kingdom

We coherently manipulate spin correlations in a two-component atomic Fermi gas loaded into an optical lattice using spatially and time-resolved Ramsey spectroscopy combined with high-resolution *in situ* imaging. This novel technique allows us not only to imprint spin patterns but also to probe the static magnetic structure factor at arbitrary wave vector, in particular the staggered structure factor. From a measurement along the diagonal of the 1^{st} Brillouin zone of the optical lattice, we determine the magnetic correlation length and the individual spatial spin correlators. At half filling, the staggered magnetic structure factor serves as a sensitive thermometer for the spin temperature, which we employ to study the thermalization of spin and density degrees of freedom during a slow quench of the lattice depth.

Q 62.8 Thu 16:15 Redoutensaal

The Bose Polaron in an ultracold Bose-Fermi mixture of ^{133}Cs and ^{6}Li — •Melina Filzinger[1], Binh Tran[1], Manuel Gerken[1], Markus Neiczer[1], Stephan Häfner[1], Bing Zhu[1], Matthias Weidemüller[1,2], Moritz Drescher[3], and Tilman Enss[3] — [1]Physikalisches Institut, Universität Heidelberg, Im Neuenheimer Feld 226, 69120 Heidelberg, Germany — [2]Shanghai Branch, University of Science and Technology of China, Shanghai 201315, China — [3]Institut für Theoretische Physik, Universität Heidelberg, Philosophenweg 19, 69120 Heidelberg

An ultracold Bose-Fermi mixture of ^{133}Cs and ^{6}Li is well suited for the investigation of the Bose polaron. In this scenario a single Li impurity is immersed in a Cs BEC and interacts with its phonon excitations, mimicking the Fröhlich polaron problem from solid-state physics. Tuning the sign and strength of the interaction between Li and Cs via Feshbach resonances enables us to study both the repulsive and attractive polaron. We are particularly interested in the study of the quench dynamics of the Bose polaron and the emergence of Efimov physics in its attractive branch.

We give an overview of our experimental approach towards creating and studying the Bose polaron in our system. With an improved imaging system and radiofrequency-setup we are able to manipulate and detect small numbers of Li impurities in a controlled way. Combining our experimental efforts with theoretical investigations of the BEC density profile after a quench, we are aiming to distinguish the Landau-Pekar and bubble polaron.

Q 62.9 Thu 16:15 Redoutensaal

Towards double degeneracy of a Bose-Fermi mixture of ^{133}Cs and ^{6}Li — •Markus Neiczer[1], Manuel Gerken[1], Binh Tran[1], Melina Filzinger[1], Stephan Häfner[1], Bing Zhu[1], and Matthias Weidemüller[1,2] — [1]Physikalisches Institut, Universität Heidelberg, Im Neuenheimer Feld 226, 69120 Heidelberg, Germany — [2]Shanghai Branch, University of Science and Technology of China, Shanghai 201315, China

An ultracold Bose-Fermi mixture of ^{133}Cs and ^{6}Li is an interesting system for the study of ground state polar molecules due to the large electric dipole moment as well as for the investigation of polarons because of the large mass imbalance and the tuneability of intra- and interspecies interactions. For these studies reaching a doubly degenerate quantum gas is a favourable experimental condition. We design a new cooling and trapping scheme for ^{6}Li which combines a time averaged crossed dipole trap and gray molasses cooling, improving the starting conditions for further evaporative cooling. The enhanced phase space density of ^{6}Li atoms allows for sympathetic cooling of ^{133}Cs, aiming for double degeneracy.

Q 62.10 Thu 16:15 Redoutensaal

Higher partial wave Feshbach resonances in an ultracold mixture of ^{6}Li and ^{133}Cs atoms — •Manuel Gerken[1], Stephan Häfner[1], Bing Zhu[1], Binh Tran[1], Juris Ulmanis[1], Eberhard Tiemann[2], and Matthias Weidemüller[1,3] — [1]Physikalisches Institut, Universität Heidelberg, Im Neuenheimer Feld 226, 69120 Heidelberg, Germany — [2]Institut für Quantenoptik, Leibniz Universität Hannover, Welfengarten 1, 30167 Hannover, Germany — [3]Shanghai Branch, University of Science and Technology of China, Shanghai 201315, China

We present measurements and analysis of higher partial wave Feshbach resonances in an ultracold mixture of fermionic ^{6}Li and bosonic ^{133}Cs atoms. We observe five p-wave ($l = 1$) and three d-wave ($l = 2$) resonances in the two energetically lowest entrance channels by magnetic field dependent atom-loss spectroscopy. We observe doublet and triplet structures in the p-wave resonances corresponding to different m_l, the projections of the pair rotation angular momentum. We attribute the lifted degeneracy in the m_l states to spin-spin and spin-rotation coupling in the molecules. The observed d-wave Feshbach resonances allow us to refine the LiCs singlet and triplet molecular potential curves at large internuclear separations.

Q 62.11 Thu 16:15 Redoutensaal

Interacting Rydberg Polaritons for Photonic Quantum Logic — •Thomas Stolz, Steffen Schmidt-Eberle, Daniel Tiarks, Stephan Dürr, and Gerhard Rempe — Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Str. 1, 85748 Garching, Germany

The strong dipole-dipole interaction between Rydberg atoms has enabled remarkable experimental success ranging from quantum information processing with single atoms to observation of exotic many-body states. The interaction between Rydberg excitations can also be used to create a large effective interaction between photons. To this end, one addresses Rydberg states with electromagnetically induced transparency. This creates a quasiparticle, called Rydberg polariton, which consists of a photonic component and a co-propagating atomic Rydberg excitation. The large interaction between the Rydberg components manifests itself in the form of a giant optical nonlinearity [1]. A central goal in the field of Rydberg polaritons is the realization of photonic quantum logic. This line of research has seen impressive progress in the last few years, including the demonstration of single-photon transistors [2,3,4] and the observation of large conditional phase shifts at the single photon level [5,6]. We report on our recent progress on using Rydberg polaritons for photonic quantum logic.

[1] J. D. Pritchard et al. PRL **105**, 193603 (2010). [2] S. Baur et al. PRL **112**, 073901 (2014). [3] H. Gorniaczyk et al. PRL **113**, 053601 (2014). [4] D. Tiarks et al. PRL **113**, 053602 (2014). [5] D. Tiarks et al. Sci. Adv. **2**, e1600036 (2016). [6] J. D. Thompson et al. Nature **542**, 206 (2017).

Q 62.12 Thu 16:15 Redoutensaal

Towards an efficient on-demand single-photon source based on atomic microcells — •Florian Christaller, Fabian Ripka, Hao Zhang, Annika Belz, Harald Kübler, Robert Löw, and Tilman Pfau — 5. Physikalisches Institut and IQST, Universität Stuttgart, Pfaffenwaldring 57, 70569 Stuttgart

Photonic quantum devices based on atomic vapors at room temperature combine the advantages of atomic vapors being intrinsically reproducable as well as semiconductor-based concepts being scalable and integrable. One key device in the field of quantum information are on-demand single-photon sources. A promising candidate for realization relies on the Rydberg blockade effect.

Coherent dynamics to Rydberg states [1] and sufficient Rydberg interaction strengths [2] have already been demonstrated in thermal vapors. Also in a pulsed FWM scheme these phenomena could be observed [3,4]. Additionally, time-resolved probing of collective Rydberg excitation has been performed [5], revealing a lifetime long enough for effective Rydberg-Rydberg interactions.

Here we report on different multi-level schemes which exploit the latest developments in laser technology. We aim at high repetition rate and high fidelity of single-photon generation.

[1] Huber et al., PRL 107, 243001 (2011)
[2] Baluktsian et al., PRL 110, 123001 (2013)
[3] Huber et al., PRA 90, 053806 (2014)
[4] Chen et al., Appl. Phys. B, 122:18 (2016)
[5] Ripka et al., Phys. Rev. A, 053429 (2016)

Q 62.13 Thu 16:15 Redoutensaal

Surface Plasmon Enhanced Multipole Transitions of Rydberg Atoms — •Yijia Zhou and Weibin Li — School of Physics and Astronomy, University of Nottingham, University Park, Nottingham, NG7 2RD, UK

The dipole approximation is widely used in describing light-matter interactions due to the fact that sizes of emitters are far smaller than wave lengths of the coupling light. This is changed qualitatively when an emitter approaches to two dimensional surfaces, where dispersion relations of surface plasmons turn out to be nonlinear and their wave length can be shrunken up to hundreds of times relative to light in free space. This can enhance the otherwise forbidden higher order multipolar transitions and multiphoton emissions (Rivera2016). Emitters have to be located a few nm above the surface, and that the shrinking factor is typically larger 100, which are experimentally challenging. We study nondipole effects using Rydberg atoms instead of groundstate atoms. Large orbital sizes of the electron in electronically high-lying states bring an additional amplifying factor to the light-atom coupling, which depends nonlinearly on the principal quantum numbers n. When $n \gg 1$, this significantly enhances multipolar couplings, permitting us to observe these effects with smaller shrinking factors, as well as at large separations between Rydberg atoms and the surface.

Q 62.14 Thu 16:15 Redoutensaal

Rydberg excitations of cold atoms inside a hollow-core fiber — •Parvez Islam, Maria Langbecker, Mohammad Noaman, Chantal Voss, Ronja Wirtz, Wei Li, and Patrick Windpassinger — Institut für Physik, Johannes Gutenberg-Universität

Mainz, Staudingerweg 7, 55128 Mainz, Germany

Cold atoms inside hollow-core fibers present a promising candidate to study strongly coupled light-matter systems. Combined with the long range Rydberg interaction which is controlled through an EIT process, a corresponding experimental setup should allow for the generation of a strong and tunable polariton interaction.

We present our measurements of cold Rydberg excitations inside a hollow-core fiber to characterize the Rydberg atom-fiber interaction by using electromagnetically induced transparency (EIT) signals [1]. A time resolved detection method was implemented to distinguish between EIT excitation and atom loss. In a separate setup at room temperature, we also investigate the influence of different types of fiber coatings and geometries on Rydberg EIT. Here we observe signals for levels up to the 85D state.

[1] M. Langbecker, M. Noaman, N. Kjaergaard, F. Benabid, and P. Windpassinger, Phys. Rev A 96, 041402(R) (2017).

Q 62.15 Thu 16:15 Redoutensaal

3D image reconstruction using symmetries applied to cold Rydberg gases — •Henrik Zahn[1], Renato Ferracini Alves[1], Miguel Ferreira Cao[1], Titus Franz[1], Adrien Signoles[2], Nithiwadee Thaicharoen[1], Gerhard Zürn[1], and Matthias Weidemüller[1,3] — [1]Physikalisches Institut, Universität Heidelberg, Im Neuenheimer Feld 226, 69120 Heidelberg, Germany — [2]Laboratoire Charles Fabry, Institut d'Optique, 2 Avenue Augustin Fresnel 91127 Palaiseau -France — [3]Shanghai Branch, University of Science and Technology of China, Shanghai 201315, China

This poster introduces an algorithm to reconstruct a three dimensional object from its two dimensional projection. It discretizes the problem in a coordinate system given by *a priori* knowledge of the object's symmetry. The resulting system of linear equations can be solved in a least squares sense. The method is applied to a strongly interacting Rydberg gas in order to study saturation effects and scaling laws in the excitation dynamics.

Q 62.16 Thu 16:15 Redoutensaal

Measuring non-linear susceptibility in a Rydberg EIT medium — •Clément Hainaut[1], Annika Tebben[1], Valentin Walther[2], Renato Ferracini Alves[1], Yongchang Zhang[2], Andre Salzinger[1], Nithiwadee Thaicharoen[1], Gerhard Zürn[1], Thomas Pohl[2], and Matthias Weidemüller[1,3] — [1]Physikalisches Institut, Ruprecht-Karls Universität Heidelberg, Im Neuenheimer Feld 226, 69129 Heidelberg, Germany — [2]Department of Physics and Astronomy, Ny Munkegade 120, building 1525 420, 8000 Aarhus C, Denmark — [3]Shanghai Branch, University of Science and Technology of China, Shanghai 201315, China

Rydberg-Rydberg interactions affect the propagation of light in a cold atomic gas under EIT conditions. Due to this interaction, the system reveals an effective photon-photon interaction which results in a non-local, non-linear susceptibility of the medium.

In our work, we want to experimentally measure the enhancement of the susceptibility due to resonant Rydberg dressing of the atoms. To do so, we work in the limit of low optical density of the probe beam per blockade radius. In this regime, the probe light field experiences substantial non-linear effects which affect its intensity distribution after propagation. We implement a spatially structured probe beam and a diffraction limited imaging system for measuring correlations in the intensity pattern after propagation through the medium.

Q 62.17 Thu 16:15 Redoutensaal

Relaxation of an isolated Rydberg-spin system in an external field — •Nithiwadee Thaicharoen[1], Adrien Signoles[1], Miguel Ferreira-Cao[1], Renato Ferracini Alves[1], Titus Franz[1], Andre Salzinger[1], Asier Piñeiro Orioli[2], Martin Gärttner[3], Jürgen Berges[2,4], Shannon Whitlock[1,5], Gerhard Zürn[1], and Matthias Weidemüller[1,6] — [1]Physikalisches Institut, Universität Heidelberg, Germany — [2]Institut für Theoretische Physik, Universität Heidelberg, Germany — [3]Kirchhoff-Institut für Physik, Universität Heidelberg, Germany — [4]ExtreMe Matter Institute EMMI, Darmstadt, Germany — [5]IPCMS and ISIS, University of Strasbourg and CNRS, Strasbourg, France — [6]Shanghai Branch, University of Science and Technology of China, Shanghai, China

Dipolar interacting Rydberg spin systems have been ideal platforms to study non-equilibrium phenomena of isolated quantum systems. Their long-range interactions provide opportunities to investigate dynamics of correlated many-body quantum systems with beyond nearest-neighbor coupling. In this work, we present an experimental realization of a dipolar spin-1/2 model by coupling two strongly interacting Rydberg states utilizing a microwave field. With an ability to fully control phase, amplitude, and frequency of the microwave field, we perform arbitrary initial state preparation and study time evolution of the spin system under designated interactions. The resulting global magnetizations together with theoretical models suggest that the relaxation of the spin system is due to primordial quantum fluctuations while single particle decoherence does not play an important role.

Q 62.18 Thu 16:15 Redoutensaal

Kinetic Field Theory - From cosmology to cold atoms — •Andre Salzinger[1], Elena Kozlikin[2], Martin Pauly[2], Alexander Schuckert[3], Robert Lilow[2], Matthias Bartelmann[2], and Matthias Weidemüller[1,4] — [1]Physikalisches Institut, Heidelberg — [2]Institut für Theoretische Astrophysik, Heidelberg — [3]Institut für Theoretische Physik, Heidelberg — [4]Shanghai Branch, University of Science and Technology of China, Shanghai 201315, China

Cosmic structure formation can be described by a classical path integral formalism. We apply such a theoretical framework to the evolution of two-point density correlators in an ensemble of Rydberg atoms. Initial correlations due to excitation blockade or facilitation are shown to decrease significantly faster under the influence of strong Rydberg-Rydberg interaction, compared to a free evolution. We discuss the experimental conditions under which this effect becomes strong enough to influence many-body experiments on microsecond time-scales. We further compare our computational procedure to standard methods from molecular dynamics.

Q 62.19 Thu 16:15 Redoutensaal

Proposal to identify Thermal and Non-Thermal fixed points in a strongly interacting Rydberg gas. — •Titus Franz[1], Renato Ferracini Alves[1], Miguel Ferreira Cao[1], Adrien Signoles[1], Nithiwadee Thaicharoen[1], Shannon Whitlock[1], Gerhard Zuern[1], Jürgen Berges[2], and Matthias Weidemüller[1,3] — [1]Physikalisches Institut, Universität Heidelberg, Im Neuenheimer Feld 226, 69120 Heidelberg, Germany — [2]Institut für Theoretische Physik, Universität Heidelberg, Philosophenweg 16, 69120 Heidelberg, Germany — [3]Shanghai Branch, University of Science and Technology of China, Shanghai 201315, China

Ultracold atoms excited to high lying Rydberg states offer an ideal platform for studying the non-equilibrium properties of long-range interacting quantum spin systems under a controlled environment. Due to the many competing effects like disorder, external fields and fluctuations, it is still an open question whether the system with the underlying Heisenberg XXZ-Hamiltonian equilibrates and reaches a thermal or non-thermal fixed point. This poster proposes a detection scheme for the absence of diffusion in a possible Many-Body-Localization phase by a measurement of the breakdown of Linear Response Theorem and the persistence of initial order after relaxation dynamics.

Q 62.20 Thu 16:15 Redoutensaal

Measuring Spin Magnetization in a Two-Level Rydberg System Using State Selective Field Ionization — •Alexander Müller[1], Renato Ferracini Alves[1], Titus Franz[1], Clément Hainaut[1], Nithiwadee Thaicharoen[1], Gerhard Zürn[1], and Matthias Weidemüller[1,2] — [1]Physikalisches Institut, Ruprecht-Karls-Universität, Heidelberg, Germany — [2]Shanghai Branch, University of Science and Technology of China, Shanghai 201315, China

We use a strongly interacting Rydberg sample to implement a spin 1/2 system composed of two different Rydberg levels. In order to accurately measure the global spin magnetization, we will implement a state selective field ionization scheme. This will be done by ramping an electrical field to temporally separate the ionization for different Rydberg levels. We will present first measurements of the ion signal from a micro-channel plate detector, calculations for the ionization probability of Rydberg atoms in a ramped electrical field and calculations of the ion trajectories. In the future, this technique will be used to study relaxation spin-dynamics and to test Thermalization in linear response theory.

Q 62.21 Thu 16:15 Redoutensaal

High resolution microscopy of cold atoms — Lea Steinert, •Raphael Nold, Markus Stecker, József Fortágh, and Andreas Günther — Center for Quantum Science, Physikalisches Institut, Eberhard Karls Universität Tübingen, Auf der Morgenstelle 14, D-72076 Tübingen, Germany

We have developed a novel quantum gas microscope based on ionization of atoms and a high resolution ion optics. The system achieves a magnification up to 1000 and a theoretical resolution limit below 100nm. The microscope consists of four electrostatic lenses and a microchannel plate in conjunction with a delay line detector. This allows for observation of ultracold ground state as well as Rydberg atoms with single atom sensitivity and high temporal and spatial resolution.

In our experiments, we use the high temporal resolution of the ion-microscope to measure the resonant dipole-dipole interaction of Förster resonances via state selective field ionization. Additionally, we show a direct measurement of the excitation blockade for strongly Stark-shifted Rydberg states close to the classical ionization limit. In this regime, the blockade radius can be sensitively adjusted by small changes of the electric field, opening up new perspectives for quantum simulators.

Q 62.22 Thu 16:15 Redoutensaal

Tailoring ionization of highly Stark shifted Rubidium Rydberg states — •Jens Grimmel, Markus Stecker, Manuel Kaiser, Peter Zwissler, Florian Karlewski, Andreas Günther, and József Fortágh — Center for Quantum Science, Physikalisches Institut, Eberhard Karls Universität Tübingen, Auf der Morgenstelle 14, D-72076 Tübingen,

Rydberg atoms are extremely sensitive to electric fields and consequently have a rich Stark spectrum. At sufficiently high electric fields these states start to ionize due to tunneling through the potential barrier as well as direct coupling to the continuum. This region is of particular interest for tailoring the ionization process to certain needs, for example in order to create cold ions and electrons for microscopy applications.

In our numerical calculations we calculate the eigenvalues and eigenvectors of a matrix representation of a Hamiltonian including a complex absorbing potential (CAP) to accurately predict the ionization spectra of Rydberg states beyond the classical ionization threshold. The CAP is adjusted to the external electric field, which allows us to calculate a whole range of the spectrum with only one free parameter. We find good agreement between the results from these calculations and the experimental data of Stark maps for Rubidium Rydberg atoms with principal quantum numbers up to 70 and are able to identify Stark shifted states with ionization rates that can be controlled by fine tuning the external electric field.

Q 62.23 Thu 16:15 Redoutensaal

Design and characterization of a low-cost cateye laser for scientific applications — •Shubha Deutschle, Simon Schuster, Philip Wolf, Max Eisele, Sonja Lorenz, Claus Zimmermann, József Fortágh, and Andreas Günther — Center for Quantum Science, Physikalisches Institut, Eberhard Karls Universität Tübingen, Auf der Morgenstelle 14, D-72076 Tübingen

For various applications in quantum optics, tunable lasers with single mode operation, narrow linewidth and high mechanical stability are required. We show the setup and design of an affordable external cavity diode laser, which meets these requirements using a retroreflective system, an interference filter and wedge prisms for easy adjustment of the beam path. The laser is equipped with a self-build electronic board, holding a diode protection circuit and a frequency modulation unit. With a bandwidth of 40MHz, it can be used for multiple laser locking schemes. We measure the linewidth of the laser, using a self-heterodyne interferometer, to be 50 kHz.

Q 62.24 Thu 16:15 Redoutensaal

Optical transport of ultracold atoms for the production of groundstate RbYb — •Tobias Franzen, Bastian Pollklesener, Alexander Mietke, and Axel Görlitz — Institut für Experimentalphysik, Heinrich-Heine-Universität Düsseldorf

Ultracold dipolar molecules constitute a promising system for the investigation of topics like ultracold chemistry, novel interactions in quantum gases, precision measurements and quantum information.

Here we report on a versatile transport apparatus for the production of ultracold RbYb molecules. This setup constitutes an improvement of our old apparatus, where the interactions in RbYb and possible routes to molecule production have already been studied extensively [1,2]. In the new setup a major goal is the efficient production of ground state RbYb molecules.

We employ optical tweezers to transport individually cooled samples of ultracold Rb and Yb from their separate production chambers to a dedicated science chamber. Here we transfer the atoms to a crossed dipole trap, where further evaporative cooling creates a starting point for the exploration of interspecies interactions and pathways towards ground state molecules.

[1] M. Borkowski et al., PRA 88, 052708 (2013)
[2] C. Bruni et al., PRA 94, 022503 (2016)

Q 62.25 Thu 16:15 Redoutensaal

Cavity-controlled chemical reactions of ultracold atoms — Tobias Kampschulte[1], •Simon Rupp[1], Jan Schnabel[2], Andreas Köhn[2], and Johannes Hecker Denschlag[1] — [1]Inst. f. Quantenmaterie, Universität Ulm — [2]Inst. f. Theoretische Chemie, Universität Stuttgart

Ultracold molecules can be formed from ultracold atoms by photoassociation involving a spontaneous emission process, resulting in a number of final states. Here we want to use strong coupling to an optical cavity to selectively enhance the creation of a certain final state. During this process, a photon will be emitted into the cavity mode which can be detected. A collective enhancement of the effect would enable "superradiant chemistry".

In addition, we want to use the cavity for direct, state-selective and non-destructive optical detection of ultracold molecules. Moreover, collective probing of an ensemble of molecules could induce nonclassical correlations, such as squeezed states of a molecular degree of freedom.

For the experiment, we are integrating a high-finesse optical microcavity into an existing Rb_2 BEC apparatus where Rb_2 molecules can be produced by magneto- and photoassociation.

The theoretical challenge lies in the precise calculation of molecular potential surfaces and optical transition moments, in particular for trimers and more complex molecules.

Q 62.26 Thu 16:15 Redoutensaal

Formation of ultracold ^{6}Li^{133}Cs Feshbach molecules — •Jonas Matthies[1], Manuel Gerken[1], Binh Tran[1], Stephan Häfner[1], Melina Filzinger[1], Markus Neiczer[1], Bing Zhu[1], and Matthias Weidemüller[1,2] — [1]Physikalisches Institut, Universität Heidelberg, Im Neuenheimer Feld 226, 69120 Heidelberg, Germany — [2]Shanghai Branch, University of Science and Technology of China, Shanghai 201315, China

An ultracold Bose-Fermi mixture of ^{133}Cs and ^{6}Li is well suited for the study of a dipolar gas of ultracold ground state molecules with large dipole moments. The formation of Feshbach molecules is a prerequisite for the creation of ground state molecules by coherent transfer through a stimulated Raman adiabatic passage (STIRAP). We report on the formation of ^{6}Li^{133}Cs Feshbach molecules via the magneto-association technique. The Feshbach molecules are investigated at three s-wave resonances with widths of 0.37G, 4.22G and 57.45G. We compare the formation efficiency and lifetime of the molecules for the three different resonances and identify the best conditions for STIRAP transfer.

Q 62.27 Thu 16:15 Redoutensaal

Feshbach resonances and degenerate quantum mixtures of bosonic sodium and potassium — •Philipp Gersema, Torben Schulze, Torsten Hartmann, Kai Voges, Jannis Schnars, Matthias Gempel, Eberhard Tiemann, Alessandro Zenesini, and Silke Ospelkaus — Institut für Quantenoptik, Leibniz Universität Hannover

Ultracold polar ground state molecules provide an excellent basis for the studies of quantum chemistry and exotic dipolar quantum phenomena. A good and well known starting point for the production of these molecules are ultracold atomic quantum gas mixtures.

Among the alkali atoms, sodium and potassium serve as ideal candidates for the production and investigation of cold molecules. Cooling strategies for both species are well explored, and NaK molecules in their rovibrational ground state feature a large dipole moment as well as chemical stability against exchange reactions.

We present our current effort towards the production of ultracold bosonic ^{23}Na^{39}K molecules. To this end, we study the scattering properties in different spin states by experimentally observing several magnetic Feshbach resonances and loss minima. These provide us highly tunable tools which we employ to succesfully create quantum degenerate Bose-Bose mixtures. In addition, we describe our progress for the production of Feshbach molecules and the envisioned coherent two-photon pathway into ground state molecules.

Q 62.28 Thu 16:15 Redoutensaal

A magic 1D lattice for ultracold, polar NaK molecules —

•Frauke Seesselberg[1], Xin-Yu Luo[1], Ming Li[2], Scott Eustice[1], Svetlana Kotochigova[2], Immanuel Bloch[1], and Christoph Gohle[1,3] — [1]Max-Planck-Institut für Quantenoptik, Garching, Germany — [2]Department of Physics, Temple University, Philadelphia, USA — [3]Ludwig-Maximilians-Universität, München, Germany

Quantum gases of polar molecules allow for dipolar interactions in quantum simulation. They have large dipole moments at long lifetimes, which make them ideal for realizing long range physics beyond nearest neighbor interactions.

The rotational degree of freedom of molecules can be used to encode spins. Due to the different parity of ground and first excited rotational state their polarizabilities at optical frequencies can however differ significantly, which leads to decoherence in an optical dipole trap. The polarization of the trapping field can be used to tune this difference and even to achieve a magic condition, where it is zero. Then long coherence times between the two states should be achievable.

We experimentally explore the first excited rotational state manifold of fermionic NaK using microwave spectroscopy. We demonstrate how small static electric fields can be used to decouple nuclear spin and molecular rotation and thus to simplify the complex rotational state spectrum and allowing an even longer coherence time. We characterize the molecular polarizabilities in a 1550 nm 1D lattice and investigate physics around the magic angle.

Q 62.29 Thu 16:15 Redoutensaal

A 3D Optical Lattice for the Creation of a Dense, Ultracold 23Na40K Gas — •Scott Eustice[1], Xin-Yu Luo[1], Frauke Seesselberg[1], Immanuel Bloch[1,2], and Christoph Gohle[1] — [1]Max-PlanckInstitut für Quantenoptik, Hans-Kopfermann-Str. 1, 85748 Garching, Germany — [2]Ludwig-Maximilians-Universität, Schellingstraße 4, 80799 München, Germany

We present the implementation of a 3D optical lattice for the production and trapping of ultracold, ground state 23Na40K molecules. Dipolar molecules can explore long-range interacting physics and the implementation of a lattice allows new regimes to be entered.

NaK molecules are created by mixing samples of Na and K, creating weakly bound Feshbach molecules, and then using STIRAP to transfer the Feshbach molecules into their ground state.

Creating large samples of NaK molecules depends on achieving a near unity filling factor of the initial Na and K atomic samples. Loading the fermionic K into the lattice is expected to give an 85% filled band insulator of 40.000 atoms. Too many bosonic Na atoms leads to greater than unity fillings, preventing molecule association. The low mass of Na compared to other bosonic atoms means that a large, unity filling Mott insulator can be created. For our experiment, we expect to obtain a 95% filled Mott insulator of 40.000 Na atoms.

With these samples, we expect Feshbach association efficiency to improve from 10% to near 100% in the lattice. We expect to achieve a final sample of 25.000 ground state NaK molecules at 60% filling, a significant improvement over previous results.

Q 62.30 Thu 16:15 Redoutensaal

Atom-chip-based interferometry with Bose-Einstein condensates — •Martina Gebbe[1], Matthias Gersemann[2], Sven Abend[2], Sven Herrmann[1], Claus Lämmerzahl[1], Ernst M. Rasel[2], and The QUANTUS Team[1,2,3,4,5,6] — [1]ZARM, Uni Bremen — [2]Institut für Quantenoptik, LU Hannover — [3]Institut für Physik, HU Berlin — [4]Institut für Quantenphysik, Uni Ulm — [5]Institut für Angewandte Physik, TU Darmstadt — [6]Institut für Physik, JGU Mainz

Atom interferometry is a well-proven tool to measure inertial forces or fundamental constants with high accuracy. Bose-Einstein condensates (BECs) or delta-kick collimated (DKC) atoms present ideal sources for precise measurements due to their small spatial and momentum width. We generate such an ensemble in a miniaturized atom-chip setup, where BEC generation and DKC can be performed fast and reliably. We present new results on our atom-chip-based gravimeter, which takes place in a volume of a one centimeter cube and comprises an innovative fountain scheme to enhance the device's sensitivity. The relaunch mechanism consists of the combination of double Bragg diffraction with Bloch oscillations. The same techniques are employed in our symmetric scalable large momentum beam splitters, which can be used in long baseline interferometry. This work is supported by the CRC 1128 geo-Q and by the German Space Agency (DLR) with funds provided by the Federal Ministry of Economic Affairs and Energy (BMWi) due to an enactment of the German Bundestag under Grant No. DLR 50WM1552-1557 (QUANTUS-IV-Fallturm).

Q 62.31 Thu 16:15 Redoutensaal

Autonomous control of a laser system for dual-species atom interferometry on board a sounding rocket — •Benjamin Wiegand[1,6], Klaus Döringshoff[1], Oliver Anton[1], Simon Kanthak[1], Markus Krutzik[1,2], Achim Peters[1,2], and The Maius team[1,2,3,4,5] — [1]Institut für Physik, HU Berlin — [2]Ferdinand-Braun-Institut, Leibniz-Institut für Höchstfrequenztechnik, Berlin — [3]ZARM, Universität Bremen — [4]Institut für Physik, JGU Mainz — [5]IQO, Leibniz Universität Hannover — [6]LMU München

The MAIUS 2/3 missions aim for high-precision tests of Einstein's Equivalence principle by means of dual-species atom interferometry (AI) with BEC's of rubidium and potassium on a sounding rocket. While this platform features long microgravity times, it puts high demands on the compactness, robustness and agility of the experiment and requires a concept for autonomous operation.

In this poster, we present a laser system based on micro-integrated diode lasers that is designed for cooling, state preperation and simultaneous Raman double-diffraction interferometry to probe for differential accelerations. We report in detail on our concept for autonomous and agile frequency control of phase-locked extended cavity diode lasers (ECDL) in a dual-use configuration for laser cooling and Raman interferometry. Furthermore, we present results of environmental and performance tests of the laser system.

This work is supported by the German Space Agency (DLR) with funds provided by the Federal Ministry of Economics and Technology (BMWi) under grant number DLR50WP1432.

Q 62.32 Thu 16:15 Redoutensaal

A robust laser system for atom interferometry with rubidium on very long baselines — •Dorothee Tell, Christian Meiners, Etienne Wodey, Dennis Schlippert, Christian Schubert, Wolfgang Ertmer, and Ernst M. Rasel — Institut für Quantenoptik, Leibniz Universität Hannover, Germany

The Very Long Baseline Atom Interferometer (VLBAI) introduces a new scale of ground-based interferometers employing ultra-cold atoms on a 10 m baseline, enabling absolute measurements of gravity and its gradients with unprecedented precision and macroscopic separations of superposition states. Long distances and interferometry times pose a challenge to all the components to avoid technical limitations, questioning the scalability of known methods and constraints.

Demands on the laser system for rubidium atom interferometry comprise well-chosen seed laser frequencies, the flexibility to implement a cooling scheme ensuring low expansion rates of the atomic ensembles, and high power in large interferometry beams to reduce wavefront induced phase shifts and enable large momentum transfer beam splitters.

We will present a robust laser system relying on well established telecommunication technology at 1560 nm allowing low-noise lasers and high-power amplifiers, and using flexible single-pass second harmonic generation to create light around the rubidium D_2 transition frequency.

The VLBAI facility is a major research equipment funded by the DFG. We acknowledge support from the CRCs 1128 "geo-Q" and 1227 "DQ-mat".

Q 62.33 Thu 16:15 Redoutensaal

Quantum optics on the ISS — •Kai Frye[1], Dennis Becker[1], Christian Schubert[1], Thijs Wendrich[1], Ernst Maria Rasel[1], and BECCAL Team[1,2,3,4,5,6] — [1]LU Hannover — [2]U Ulm — [3]FBH Berlin — [4]U Berlin — [5]U Mainz — [6]ZARM at U Bremen

BECCAL will be an important milestone for the ongoing quest of further advancing quantum optics into space. A multi-user and - purpose facility will be launched to the International Space Station to perform a large variety of experiments with ultracold Rb and K atoms, therefore providing an extraordinary platform in a permanent microgravity environment.

Building upon the heritage of the MAIUS sounding rocket mission, which created the first Bose-Einstein-Condensate in space, German and American scientists jointly proposed research topics including the production of dual-species BECs, atom interferometry, ultra-cold quantum mixtures, shell geometries and spinor gases.

Our poster sketches the preliminary concepts and architecture, including the dimensions and estimated capabilities of the setup. Some crucial and newly developed components, such as a compact and robust tip-tilt mirror setup, will be presented in detail.

The BECCAL project is supported by the German Space Agency DLR with funds provided by the Federal Ministry of Economics and Technology (BMWi) under the grant numbers 50WP1431 and 50WP1700.

Q 62.34 Thu 16:15 Redoutensaal

Novel techniques for atom interferometry — •Dennis Schlippert[1], Henning Albers[1], Claus Braxmaier[2], Felipe Guzmán[2], Lee Kumanchik[2], Dipankar Nath[1], Logan Richardson[1], Simon Rossmann[1], Christian Schubert[1], Ashwin Thennadil[1], Wolfgang Ertmer[1], and Ernst Rasel[1] — [1]Institut für Quantenoptik, Leibniz Universität Hannover — [2]DLR Institut für Raumfahrtsysteme, Bremen

Today's state-of-the-art atom gravimeters require improvements in stability and accuracy in order to fully exploit their potential with large scale factors on very long baselines on ground and in space. Here we report on work towards improving the accuracy of our Rb-K-interferometer by means of a time-averaged optical dipole trap. Dynamically shaping the potential allows one to increase the initial trap volume as well as the evaporation efficiency. Likewise, the potential can be adapted for common δ-kick collimation of the dual species ensemble, eliminating a leading systematic uncertainty and improving the contrast. Moreover, we employ a novel class of highly compact opto-mechanical inertial sensors for postcorrection of seismic noise, otherwise limiting the short term stability of the atom interferometer. We show first demonstration experiments as well as future directions for broad applications of hybrid systems.

The presented work is supported by CRC 1128 geo-Q, the German Space Agency (DLR) with funds provided by the Federal Ministry of Economic Affairs and Energy (BMWi) (Grant No. 50WM1641), and through the Quantum- and Nano-Metrology (QUANOMET) initiative.

Q 62.35 Thu 16:15 Redoutensaal

Gravity sensing with Very Long Baseline Atom Interferometry — •Etienne Wodey[1], Manuel Schilling[2], Christian Meiners[1], Dorothee Tell[1], Dennis Schlippert[1], Christian Schubert[1], Ludger Timmen[2], Wolfgang Ertmer[1], Jürgen Müller[2], and Ernst M. Rasel[1] — [1]Institut für Quantenoptik, Leibniz Universität Hannover — [2]Institut für Erdmessung, Leibniz Universität Hannover

Very Long Baseline Atom Interferometry (VLBAI) represents a new generation of atom interferometry based sensors aiming at measuring inertial forces and performing tests of fundamental physics with unprecedented resolution and accuracy. An extension of the baseline from tens of centimeters to over ten meters combined with novel seismic noise reduction systems puts sensitivities competing with those of superconducting gravimeters within reach, while keeping the stability and accuracy inherent to atomic sensors. Among other applications, next generation gravity reference stations can then be envisaged.

However, performing high-accuracy atom interferometry over such extended baselines poses severe challenges to the design of the apparatus. We focus in particular on our strategies to control magnetic and gravity fields along the baseline as well as reduce the seismic noise of the inertial reference. We also present the development of our source of ultracold ytterbium atoms which, thanks to its rich energy levels structure and outstanding magnetic properties in its electronic ground state opens further prospects for high-performance atom interferometry.

This work is supported by the CRCs 1128 geo-Q and 1227 DQ-mat.

Q 62.36 Thu 16:15 Redoutensaal

Automated control-electronics for a dual species atom interferometer on a sounding rocket. — •Wolfgang Bartosch, Thijs Wendrich, Ernst Maria Rasel, and Wolfgang Ertmer — Institut für Quantenoptik, Universität Hannover

Interferometry experiments with ultra-cold degenerate quantum gases under microgravity conditions offer possibilities to test fundamental laws of physics to unprecedented precision. The MAIUS-2/3 sounding rocket missions is planned to explore dual species atom interferometry in space. Operation on sounding rockets poses strict requirements on the mass, volume, on features like reliability and robustness of the payload and the system needs to operate autonomously. 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 had to further downsize the electronic components to fit hardware for a second species in an experiment the same size. Also we had to improve our systems to deal with the various challenges that arose from the results of the MAIUS-1 mission. In this poster we present our progress on this work.

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 62.37 Thu 16:15 Redoutensaal

Operating a mobile Gravimetric Atom Interferometer GAIN at the fundamental station Wettzell — •Anne Stiekel[1], Bastian Leykauf[1], Vladimir Schkolnik[1], Christian Freier[1], Hartmut Wziontek[2], Axel Rülke[2], Markus Krutzik[1], and Achim Peters[1] — [1]Institut für Physik, Humboldt-Universität zu Berlin, Germany — [2]Bundesamt für Karthographie und Geodäsie

GAIN is an atomic interferometer based on rubidium and stimulated Raman transitions used to measure the gravitational acceleration. Its transportability makes it possible to measure at sites of geodetic and geophysical interest.

In cooperation with the German Federal Agency for Cartography and Geodesy (Bundesamt für Karthographie und Geodäsie, BKG) a measurement campaign was conducted at the geodetic observatory in Wettzell to show the performance of quantum gravity sensor.

We will show the experimental apparatus and the operation with a focus on beam alignment. New procedures were tested to adjust the setup and thus optimize the measurement.

A long-term gravity measurement was recorded and compared with a superconducting gravimeter. We will discuss the Coriolis effect and a strategy to suppress the resulting phase shift. Another objective was to analyse the effect of an active and passive vibration isolation as well as the efficiency of a post-correction.

Q 62.38 Thu 16:15 Redoutensaal

Tackling leading order uncertainties in atom gravimetry — •Nina Grove, Maral Sahelgozin, Jonas Matthias, Jan Philipp Barbey, Sven Abend, Waldemar Herr, and Ernst M. Rasel — Inst. f. Quantenoptik, Leibniz Universität Hannover

On our poster we will discuss the limiting systematic effects in state-of-the-art atom gravimeters and present our estimations for mitigating these uncertainties in our novel transportable Quantum Gravimeter QG-1. The improved performance will be made possible by employing magnetically lensed Bose-Einstein Condensates as the source for the atom interferometer, as the current generation of atom gravimeters are limited by the use of thermal laser cooled atomic ensembles. By this the leading systematic error caused by wavefront aberrations and the Coriolis force will be suppressed. Approaching an accuracy of 10^{-9}m/s^2 novel contributions to the uncertainty budget, namely shifts due to mean field energy and the Black Body Radiation, will be discussed. This work is supported by the Deutsche Forschungsgemeinschaft (DFG) as part of project A01 within the SFB 1128 geo-Q.

Q 62.39 Thu 16:15 Redoutensaal

Coherent beam combination and power actuation of high power lasers for gravitational wave detectors — Nina Bode and •Benno Willke — Max Planck Institute for Gravitational Physics, Hannover

The next generation of gravitational wave detectors, like the Einstein Telescope, are designed to reach a high sensitivity at a broad range of frequencies. At high frequencies shot noise is a fundamental limit. As the shot noise limited sensitivity improves with increasing laser power it is proposed to use a 500W laser source with a wavelength of 1064 nm.

Currently available laser sources with such a high power do not fulfill the strong power, frequency and mode stability requirements of gravitational wave detectors. The coherent beam combination of two stable 250W lasers could generate a 500W beam with the required stability.

For demonstration purposes we performed a coherent beam combination of two solid-state laser systems, at a wavelength of 1064nm, with a combination efficiency of 90%.

To handle the high power beams, we developed a fast power actuator working with the effect of frustrated total internal reflexion (FTIR).

The FTIR-actuator produces a reflected and transmitted beam, the power ratio of wich can be adjusted. We characterized the reflected and transmitted beam and found that the actuator does not signifancantly influence the spatial beam shape and the noise of both beams.

Q 62.40 Thu 16:15 Redoutensaal

Progress Towards an Al^+ Quantum Logic Optical Clock — Nils Scharnhorst[1,2], •Johannes Kramer[1], Ian D. Leroux[1], Nicolas Spethmann[1], and Piet O. Schmidt[1,2] — [1]QUEST Institute for Experimental Quantum Metrology, Physikalisch-Technische Bundesanstalt, 38116 Braunschweig, Germany — [2]Institut für Quan-

tenoptik, Leibniz Universität Hannover, 30167 Hannover, Germany

We present the status of our aluminum ion optical clock, based on a single $^{27}Al^+$ clock ion confined in a linear Paul trap together with a $^{40}Ca^+$ logic ion. The latter is used for sympathetic cooling and internal state detection of the clock ion via the Coulomb interaction. $^{27}Al^+$ provides a narrow (8 mHz) clock transition at 267 nm which exhibits negligible electric quadrupole shift and an exceptionally low sensitivity to black-body radiation. A measurement of the trap temperature combined with numerical simulations allows us to bound the black-body radiation shift to $< 10^{-19}$. Micromotion has been compensated to a level well below a fractional frequency uncertainty of 10^{-17}. We developed double-bright electromagnetically induced transparency (D-EIT) cooling [1] as novel scalable approach to standard EIT cooling. Using the D-EIT scheme we demonstrated for the first time ground-state cooling of all three motional degrees of freedom of a trapped $^{40}Ca^+$ ion within a single, short cooling pulse [1]. Our next step is to extend this technique to ground-state cooling of all six motional modes of an Al-Ca crystal. Extrapolating from the results of a single Ca^+ cooling, we expect a fractional second order Doppler shift from residual motion of well below 10^{-18}. [1] Scharnhorst et al., arXiv: 1711.00732v2 (2017)

Q 62.41 Thu 16:15 Redoutensaal

Towards a transportable ^{27}Al$^+$ quantum logic optical clock — •Lennart Pelzer[1], Stephan Hannig[1], Mariia Stepanova[1], Johannes Kramer[1], Nils Scharnhorst[1], Nicolas Spethmann[1], and Piet O. Schmidt[1,2] — [1]Physikalisch-Technische Bundesanstalt, 38116 Braunschweig, Germany — [2]Leibniz Universität Hannover, 30167 Hannover, Germany

According to Einstein's theory of relativity, optical clocks tick slower near a gravitating body. On Earth, this corresponds to a fractional frequency change of 10^{-17} for 10 cm height difference. Clock comparisons via length-stabilized optical fibers thus enable height difference measurements over long distances, realizing "relativistic geodesy" with clocks. Such measurements complement classical techniques base on spirit leveling or a combination of gravimetry and satellite positioning.

We present the status of our $^{27}Al^+$/ $^{40}Ca^+$ quantum logic optical clock. An Al^+ ion serves as the clock ion with a narrow (8mHz) transition at 267nm which is insensitive to electromagnetic line shifts. The single Al^+ ion is confined together with a single Ca^+ ion. The latter is used for sympathetic cooling to the ground state as well as the readout of the clock transition. We present a transportable setup in which many optics components are fiber-coupled. Using ablation loading we can trap single Ca^+ ions in a segmented linear Paul trap with low heating rate and small black-body radiation shift. We present first results on ground state cooling and trap characterization. The setup will be transferred into a container to demonstrate relativistic geodesy at a level of 10 cm and below.

Q 62.42 Thu 16:15 Redoutensaal

Towards a test of Local Lorentz Symmetry with ^{172}Yb$^+$ ions — •Chih-Han Yeh, André P. Kulosa, Alexandre Didier, Dimitri Kalincev, Jan Kiethe, Tabea Nordmann, Nimrod Hausser, and Tanja E. Mehlstäubler — Physikalisch-Technische Bundesanstalt, Bundesallee 100, 38166 Braunschweig, Germany

We report on an experiment to be carried out with two entangled $^{172}Yb^+$ ions which tests the Local Lorentz Invariance (LLI) in the electron-photon sector. The relevant states we use for the LLI test are the $4f^{13}6s^2\ ^2F_{7/2}$ ($m_J = |1/2|$ and $m_J = |7/2|$) substates that have orthogonal orientations which respond differently to the Lorentz-violating effect quantified by the $c'_{\mu\nu}$ tensor. This will cause the energy difference between them to change as the Earth rotates with respect to the Sun-centered frame. The ions must be prepared in a decoherence-free subspace before being mapped onto the $^2F_{7/2}$ state, since magnetic field noise will destroy the ions' state coherence. The entanglement in the $^2F_{7/2}$ state can be prepared in three theoretically promising ways: 1. via Mølmer Sørensen Gate; 2. preparing a product state which dephases into a mixed state[1]; 3. using two-frequency bichromatic laser to map the ions directly onto the $^2F_{7/2}$ state[2].

Currently we are setting up the 934nm laser which will be frequency doubled into a 467nm laser for interrogation of the octupole transition in $^{172}Yb^+$.

[1] T. Pruttivarasin et al., *Nature* **517**, 592-595 (2015).
[2] V. A. Dzuba et al., *Nature Physics* **12**, 465-468 (2016).

Q 62.43 Thu 16:15 Redoutensaal

48 cm long ultra-stable glass resonator with crystalline mirror coatings — •Steffen Sauer[1], Steffen Rühmann[1], Dominika Fim[1], Klaus Zipfel[1], Nandan Jha[1], Waldemar Friesen-Piepenbrink[1], Rasmus Holst[1], Sebastian Häfner[2], 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

Ultra-stable lasers are one of the key components utilized in optical frequency standards for probing ultra-narrow transitions. Currently, the ultimate frequency stability of resonators is limited by the thermal noise of the mirror coating. To reduce the resulting frequency instability we are setting up a resonator of 48 cm length with crystalline mirror coatings [Cole et al., Nat. Phot. **7**, 644 (2013)]. This leads to a low Brownian noise floor with a calculated fractional frequency instability of 3×10^{-17} which is competitive to cryogenic optical resonators. The system is built in cooperation with the PTB following the design in [Häfner et al., Opt. Lett. **40**, 2112 (2015)]. The resonator will be characterized against the single-crystal silicon resonators at PTB and will be used as ultra-stable local oscillator for the magnesium lattice clock experiment at IQ, Hannover. A frequency comb will transfer the frequency stability of the long resonator at 1560 nm to our current clock laser system at 916 nm, which is limited at 4×10^{-16} in 1 s. The lower frequency noise will lead to longer interrogation time, which will reduce the noise contribution of the Dick effect. We report on the progress and performance of our ultra-stable laser system.

Q 62.44 Thu 16:15 Redoutensaal

An optical lattice clock based on Magnesium — •Waldemar Friesen-Piepenbrink, Dominika Fim, Klaus Zipfel, Steffen Rühmann, Nandan Jha, Steffen Sauer, Wolfgang Ertmer, and Ernst Rasel — Leibniz Universität Hannover, Welfengarten 1, 30167 Hannover, Germany

We present the current status of our optical lattice clock based on the strongly forbidden $^1S_0 \rightarrow ^3P_0$ transition in the bosonic ^{24}Mg isotope. With its small black body radiation sensitivity, magnesium is a promising candidate for an optical frequency standard.

We are able to load 10^4 precooled bosonic magnesium atoms into an optical lattice at the magic wavelength. Due to its low mass, a high trap depth is required to significantly suppress tunneling between adjacent lattice sites and minimize the resulting linewidth for spectroscopy. At a trap depth of 50 E_{Recoil} we were able to perform spectroscopy of a 50 Hz linewidth with the highest Q value for magnesium. Together with an improved magnetic field setup, necessary for magnetic field induced spectroscopy, we were able to characterize the systematics of the clock with an uncertainty in the 10^{-15} regime.

We will give an outlook of our efforts towards further reduce the linewidth of our magnesium clock.

Q 62.45 Thu 16:15 Redoutensaal

Operating a high-accuracy lattice optical clock with a filtered tapered amplifier lattice laser — •Pramod Mysore Srinivas[1], Stefano Origlia[1], Stephen Schiller[1], Christian Lisdat[2], Uwe Sterr[2], Jürgen Stuhler[3], Stefan Baumgärtner[3], and Rudolf Neuhaus[3] — [1]Institut für experimentalphysik, Heinrich Heine Universität, 40225, Düsseldorf, Germany — [2]Physikalisch Technische Bundesanstalt, Bundesallee 100, Braunschweig, Germany — [3]Toptica Photonics AG, Lochhamer Schlag 19, 82166,Gräfelfing, Germany

In an optical lattice clock atoms are trapped and interrogated in a periodic potential generated using a strong light field (optical lattice). A shift of the clock transition frequency can be strongly suppressed by operating the lattice laser at the *magic* frequency. A high spectral purity of the lattice beam is also of critical importance for minimizing residual shifts. In tapered amplifier (TA) diode lasers the contribution of amplified spontaneous emission (ASE) is a major limiting factor for achieving clock uncertainty below 1x10-16. In this work we present the characterization of a new grating-based filter to suppress the ASE of a commercial 813 nm laser in a transportable Sr clock [1]. Its magic wavelength is compared with the one of a Ti:Sapphire laser. The optical clock frequency uncertainty due to the lattice laser is evaluated. [1] Origila et al. Proc. of SPIE 9900, 990003-1 (2016)

Q 62.46 Thu 16:15 Redoutensaal

Non-magnetic setup for an Indium multi-ion clock — •Tabea Nordmann, Hartmut Nimrod Hausser, Alexandre Didier, Jan Kiethe, and Tanja E. Mehlstäubler — Physikalisch-Technische Bundesanstalt, Braunschweig, Germany

Optical ion clocks are one of the most promising candidates to approach fractional uncertainties of 10^{-18} and below. Using N ions instead of a single ion shortens the interrogation time to reach that level by a factor 1/N compared to the latter.

In the past years we have successfully developed a new ion trapping platform which is capable of trapping ion crystals in a well-controlled environment on that accuracy level.

Here we present our new experimental apparatus for a multi-ion clock based on $^{115}In^{+}$ ions which are sympathetically cooled with $^{172}Yb^{+}$ ions in a mixed linear ion crystal.

Apart from the segmented AlN trap the new setup consists of a non-magnetic and low outgassing titanium vacuum chamber with a variety of laser access and magnetic field coils providing a B-field with estimated inhomogeneities below 15nT over the whole trapping area.

Furthermore, we discuss the laser systems for addressing the cooling and detection transition in indium ($^1S_0$ to $^3P_1$), operating at 230.6nm.

The read-out of the clock is based on simultaneously imaging both ion species on one EMCCD camera by two aspheric lenses.

Photonic crystal fibers are tested as a mode cleaner for the deep UV light at 230.6nm and 236.5nm for exciting the clock transition ($^1S_0$ to $^3P_0$).

Q 62.47 Thu 16:15 Redoutensaal

Interrogating optical clocks beyond the coherence limit of the clock laser — •Roman Schwarz[1], Ali Al-Masoudi[1], Sören Dörscher[1], Marcin Bober[2], Richard Hobson[3], Uwe Sterr[1], and Christian Lisdat[1] — [1]Physikalisch-Technische Bundesanstalt, Bundesallee 100, 38116 Braunschweig — [2]Institute of Physics, Faculty of Physics, Astronomy and Informatics, Nicolaus Copernicus University, Grudziadzka 5, 87-100 Torun, Poland — [3]National Physical Laboratory, Hampton Road, Teddington, Middlesex, UK, TW11 0LW

The performance of optical clocks benefit from ultra stable laser systems enabling several seconds of interrogation time. For longer interrogation times, the coherence time of the clock laser becomes one limiting factor. Even with state-of-the-art laser systems, the natural linewidth of the clock transition has not been reached yet. Here we present a novel interrogation method, which allows interrogation times beyond the coherence time of the laser. The proposed technique utilizes a correlated interrogation sequence of two atomic clocks with a single clock laser to resolve the phase ambiguity occurring for Ramsey interrogation beyond the coherence limit of the interrogation laser. Additionally, probing the atomic ensemble for several seconds, effects such as Raman scattering induced by the intense optical lattice may cause a frequency shift and limit the coherence time. This work is supported by QUEST, the DFG within CRC 1128 (geo- Q A03), CRC 1227 (DQ-mat B02) and RTG 1729.

Q 62.48 Thu 16:15 Redoutensaal

Twisted-light–ion interaction: the role of longitudinal fields — Guillermo. F. Quinteiro[1], Christian. T. Schmiegelow[1], and •Ferdinand Schmidt-Kaler[2] — [1]Departamento de Fisica and IFIBA, FCEN, Universidad de Buenos Aires, Ciudad Universitaria, Pabellon I, 1428 Ciudad de Buenos Aires, Argentina — [2]QUANTUM, Institut für Physik, Universität Mainz, Staudingerweg 7, 55128 Mainz, Germany

The propagation of light beams is well described using the paraxial approximation, where field components along the propagation direction are usually neglected. For strongly inhomogeneous or shaped light fields, however, this approximation may fail, leading to intriguing variations of the light-matter interaction. This is the case of twisted light having opposite orbital and spin angular momenta. We compare experimental data for the excitation of a quadrupole transition in a single trapped Ca+ ion [1] with a model where longitudinal components of the electric field are taken into account. Our model matches the experimental data and excludes by 11 standard deviations the approximation of complete transverse field [2]. This demonstrates the relevance of all field components for the interaction of twisted light with matter.

[1] Schmiegelow et al, Nat. Comm. 7, 12998 (2016)

[2] Quinteiro, Schmiegelow and Schmidt-Kaler, arXiv 1709.05571

Q 62.49 Thu 16:15 Redoutensaal

Dynamics in quantum metrology — •Lukas J. Fiderer and Daniel Braun — Universität Tübingen, Germany

The typical protocol of a quantum measurement starts with state preparation followed by dynamics that encode the parameter to be measured to the system and ends with a readout by measuring the quantum state which allows to infer the parameter. System size N and the time t, that the system evolves before it is measured, are crucial resources that determine the performance of the measurement. Measurement precision scales under "classical" conditions with $1/(\sqrt{NT})$, called standard quantum limit (SQL). It is well known that this limit can be beaten by preparing initial quantum states that are entangled, when SQL is replaced by the Heisenberg scaling $1/(NT)$. While a lot of research centres around finding beneficial entangled states to eventually beat SQL such quantum states are typically difficult to prepare and prone to decoherence. We present possibilities to improve quantum measurements under experimental feasible conditions with easily accessible, classical states. With the help of the quantum Fisher information we investigate novel types of dynamics to encode the parameter to the system. Realistic simulations prove the suitability for application in magnetic field sensors.

Q 62.50 Thu 16:15 Redoutensaal

Setup for the measurement of stress-induced optical birefringence — •Jan Meyer[1,3], Johannes Dickmann[1], Rene Glaser[2], Carol Bibiana Rojas Hurtado[1], Walter Dickmann[1,3], and Stefanie Kroker[1,3] — [1]Physikalisch-Technische Bundesanstalt Braunschweig, Bundesallee 100, Braunschweig, Germany — [2]Friedrich-Schiller-Universität Jena, Institut für Festkörperphysik, Helmholtzweg 5, Jena, Germany — [3]Technische Universität Braunschweig, LENA Laboratory for Emerging Nanometrology,Pockelsstraße 14, Braunschweig, Germany

Optomechanical systems for high-precision sensing such as optical ring resonators or gravitational wave detectors require a detailed knowledge of mechanical and optical material parameters.

We introduce a versatile setup for the dynamic measurement of optical and mechanical properties, for example of mechanical loss, birefringence and elastic tensors. To perform frequency dependent (resonant and off-resonant) investigations we drive the samples by piezo-electric actuators or strong quasi-electrostatic fields. The mechanical motion of the sample is monitored by a fringe-locked Michelson Interferometer based on a stabilized 632 nm HeNe-Laser. To measure the dynamically induced birefringence we couple the setup to a tunable light source (300 nm...2000 nm) based on a Czerny-Turner monochromator that can be flexibly connected to either an ellipsometer or Mach-Zehnder interferometer.

Q 62.51 Thu 16:15 Redoutensaal

High frequency precision quantum metrology — •Nicolas Staudenmaier[1], Simon Schmitt[1], Liam P. McGuinness[1,2], and Fedor Jelezko[1,2] — [1]Institute for Quantum Optics, Ulm University, Albert-Einstein-Allee 11, Ulm 89081, Germany — [2]Center for Integrated Quantum Science and Technology, Ulm University, Albert-Einstein-Allee 11, Ulm 89081, Germany

Due to their small size and high sensitivity, nitrogen vacancy centers in diamonds are excellent sensors for nanoscale nuclear and electron magnetic resonance experiments. Recently, detection of single molecules and the study of their structure and dynamics has been demonstrated. A crucial point for single molecule spectroscopy is the spectral resolution. It was shown that the spectral precision of NV magnetometry can exceed the sensor coherence time and is only limited by the clock stability of an external oscillator [1]. While previous experiments were restricted to measure frequencies up to a few MHz, here we present and discuss a new technique which extends the measurement range to high frequency fields. The new technique we demonstrate allows detection of a GHz magnetic field with sub-Hz linewidth, using a quantum coherent sensor.

[1] Simon Schmitt et al. "Submillihertz magnetic spectroscopy performed with a nanoscale quantum sensor." Science 356 (2017): 832-837

Q 62.52 Thu 16:15 Redoutensaal

Towards ultrasensitive mass sensing using single spins in diamond — •Tetyana Shalomayeva[1], Thomas Oeckinghaus[1], Ali Momenzadeh[1], Dominik Schmid-Lorch[1], Durga Dasari[1,2], Amit Finkler[3], Rainer Stöhr[1], and Jörg Wrachtrup[1,2] — [1]3rd Institute of Physics, University of Stuttgart — [2]Max Planck Institute for Solid State Research — [3]Department of Chemical and Biological Physics Weizmann Institute of Science

Quantum sensing has emerged recently as the breakthrough application of spin defects in solids. In this regard, negatively-charged nitrogen vacancy centers (NV) in diamond are presented as ultrasensitive sensors of magnetic field [1], electric field [2], temperature [3], stress and pressure [4,5], and force [6]. Here, ultrasensitive measurement of mass employing NV centers as embedded nanosensors in diamond micromechanical oscillators is discussed. Different techniques such as optical readout of the oscillator position and ODMR-based measurements are analytically discussed and compared. This is followed by a demonstration of the experimental realization of the platform and mass-sensing results.

[1] G. Balasubramanian et al. Nature 455, 648-651 (2008) [2] F. Dolde et al. Nature Physics 7, 459-463 (2011) [3] P. Neumann et al. Nano Lett., 2013, 13 (6), pp 2738-2742 [4] J. Teissier et al. Phys. Rev. Lett. 113, 020503 (2014) [5] S. A. Momenzadeh et al. Phys. Rev. Applied 6, 024026 (2016) [6] M. S. J. Barson et al. Nano Lett., 2017, 17 (3), pp 1496-1503

Q 62.53 Thu 16:15 Redoutensaal

Coarse-grained master equation for an optical dense atomic ensemble — •Aleksei Konovalov, Andreas Alexander Buchheit, and Giovanna Morigi — Saarland University, 66123 Saarbrücken

We apply the coarse-graining method to derive a master equation of an ensemble of atoms interacting with the electromagnetic field. For a single atom such master equation naturally includes terms due to quantum interference in the decay channels and fulfills the requirements of the Lindblad theorem without any phenomenological assumptions (see Phys. Rev. A 94, 042111 (2016)). An extension of this theoretical approach for describing the atomic emission behavior of an ensemble of atoms requires taking into account the interaction between the atoms, thus also quantum interference due to dipole-dipole interactions at different transition frequencies. We discuss the effect that these additional terms can have on light propagation in an optically dense medium.

Q 62.54 Thu 16:15 Redoutensaal

Collective hyperfine splitting in resonant x-rays scattering — •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 systems of ^{57}Fe nuclei under the action of an external magnetic field, where a collective contribution to the level shifts appears that can amount to seizable deviations from the single-atom magnetic hyperfine splitting. We develop a formalism to describe single-photon superradiance in multi-level systems and identify three parameter regimes, two of which present measurable deviations in the radiation spectrum compared to the case of single-nucleus magnetic-field-induced splitting [2]. All three regimes should be realizable in planar x-ray cavities with an embedded nuclear layer under experimental parameters available today.

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

Q 62.55 Thu 16:15 Redoutensaal

Polaritonic Contribution to the Casimir Interaction in Graphene Systems — •Christoph Egerland[1,2], Francesco Intravaia[2], 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 a phenomenon where two uncharged bodies placed in vacuum attract each other due to quantum or thermal fluctuations. In addition to its fundamental interest, the Casimir force also has important technological implications, since it can cause sticking or jamming between parts of nanodevices. To control these (often unwanted) effects, one can leverage on the so-called surface polaritons, i.e. material excitations living at the surface of the bodies. They indeed dominate the Casimir interaction in the limit of small separations. Recently, due to its prospective applications in nanotechnology, a lot of attention was devoted to the calculation of the Casimir force in graphene systems.

We examine in detail the contribution of the polaritonic modes to the Casimir interaction between two parallel layers of graphene. We put a special emphasis on the material model chosen to describe graphene and we consider some specific features such as a non-vanishing band gap.

Q 62.56 Thu 16:15 Redoutensaal

Proximity force approximation and specular reflection: application of WKB Mie scattering to the Casimir effect — •Benjamin Spreng[1], Michael Hartmann[1], Vinicius Henning[2], Paulo A. Maia Neto[2], and Gert-Ludwig Ingold[1] — [1]Universität Augsburg, Institut für Physik, 86135 Augsburg, Germany — [2]Instituto de Física, UFRJ, Rio de Janeiro, Brazil

The electromagnetic Casimir interaction between two spheres is studied within the scattering approach using the plane-wave basis. It is demonstrated that the proximity force approximation (PFA) corresponds to the specular-reflection limit of Mie scattering. Using the leading-order semiclassical WKB approximation for the direct reflection term in the Debye expansion for the scattering amplitudes, we prove that PFA provides the correct leading-order divergence for arbitrary materials and temperatures in the sphere-sphere and the plane-sphere geometry.

Q 62.57 Thu 16:15 Redoutensaal

Towards chiral cavity quantum electrodynamics with ensembles of atoms around an optical nanofiber — •Aisling Johnson, Martin Blaha, Alexander Ulanov, Philipp Schneeweiss, and Arno Rauschenbeutel — TU Wien - Atominstitut, Stadionallee 2, 1020 Wien

Interfacing atoms with light propagating through an optical nanofiber is a promising method for the study of light-matter interaction. We are currently developing an experiment based on such a nanofiber to probe new regimes of cavity quantum electrodynamics (cQED). The tapered nanofiber, including the 500 nm thick waist, is connected to a fiber ring resonator. By creating a MOT cloud around the waist, we can couple an ensemble of atoms to the cavity field which propagates as an evanescent field in this region where the cross-section of the fiber is smaller than the wavelength of light. Notably, the polarization properties of light in the tapered fiber can lead to chiral, i.e propagation-direction dependent, light-matter interaction, which is expected to strongly affect the collective behavior of the atomic cloud in the cavity field. In general this setup should lend itself well to novel cQED experiments as well as quantum simulation of strongly coupled light and matter.

Q 62.58 Thu 16:15 Redoutensaal

Optical Heterodyne Detection of a Cross-Phase Modulation Mediated by a Single Atom — •Jonas Neumeier, Nicolas Tolazzi, Bo Wang, Gang Li, Tatjana Wilk, and Gerhard Rempe — Max Planck Institute of Quantum Optics, Hans-Kopfermann-Straße 1, 85748 Garching

Controlled interactions between individual photons are of fundamental interest. Cavity quantum electrodynamics in the regime of strong light-matter coupling provides a promising platform for implementing nonlinear interactions. In our experiment, two separate transitions of a four level atom in an N-type scheme are strongly-coupled to two distinct modes of a cavity that are driven by light fields at wavelengths 780 nm and 795 nm. A control laser induces coupling between these modes resulting in either mutual blocking or conjunct tunnelling of photons. Moving one of the modes to the dispersive regime makes non-destructive all-optical sensing of the photon number feasible [1]. It can be understood as the result of a photon number dependent Stark shift [2]. In addition, cross-phase modulation is expected: single photons present in one mode induce a significant phase shift on photons in the other mode. Recently, an optical heterodyne detection setup has been added to the experiment, making the measurement of this cross-phase modulation reachable. The setup combines analog downmixing with FPGA assisted data acquisition, offering direct digitization of both quadratures at a relatively low data rate.

[1]Schuster el al., Nature 445, 515-518 (2007)
[2]Albert et al., Nature Photonics 5, 633-636 (2011)

Q 62.59 Thu 16:15 Redoutensaal

Fiber-cavity-based single-photon single-atom interface — •Elvira Keiler, Wolfgang Alt, Jose Gallego, Tobias Macha, Deepak Pandey, Eduardo Uruñuela, Jian Wang, and Dieter Meschede — Institut für Angewandte Physik der Universität Bonn, Wegelerstr. 8, 53115 Bonn

We present our work on a photon-atom interface composed of an optical fiber-based Fabry-Pérot cavity and small ^{87}Rb ensembles. The small mode volume of fiber cavities allows us to remain in the strong coupling regime even for high cavity bandwidths. In this way, photon pulses even shorter than the atomic lifetime can be stored in the ensemble via stimulated Raman adiabatic passages. For this method, we calculate optimal pulse shapes [1] and generate them with a combination of fast arbitrary waveform generators and electro-optical modulators. Since the photon can be retrieved with the readout Raman pulse, the system realizes one of the building blocks necessary for quantum repeaters.

[1] Jerome Dilley, Peter Nisbet-Jones, Bruce W. Shore, and Axel Kuhn, Single-photon absorption in coupled atom-cavity systems, Phys. Rev. A 85, 023834 (2012).

Q 62.60 Thu 16:15 Redoutensaal

Strong Coupling between Photons via a four-level N-type atom — •Bo Wang, Nicolas Tolazzi, Jonas Neumeier, Christoph Hamsen, Gang Li, Tatjana Wilk, and Gerhard Rempe — Max Planck Institute of Quantum Optics, Hans-Kopfermann-Str. 1, 85748 Garching, Germany

Four-level N-type atomic systems have been investigated for effects like the electromagnetically induced absorption (EIA) and cross-phase modulation (XPM) when interacting with classical light fields[1]. Despite the giant nonlinearity, the interaction strengths are negligible at the level of individual quanta. However with the strong light matter coupling provided by cavity quantum elecrodynamics, a significant interaction between single photons can be reached. Here we report on an experiment where the photons of two light fields are strongly coupled via a single four-level N-type atom. The fields drive two modes of an optical cavity, which are strongly coupled to two separate transitions. A control laser drives one transition's ground state to the other transition's excited state, the inner transition of the N-type atom. It induces a tunable coupling between the modes and results in a doubly nonlinear energy-level structure of the photon-photon-atom system. The strong correlation between the light fields is observed via photon-photon blocking and photon-photon tunneling. With this new system, nondestructive counting of photons and heralded n-photon sources might be within reach.

[1]Li S, Yang X, Cao X, Zhang C, Xie C, Wang H, Phys. Rev. Lett. 101(7)(2008) 073602.

Q 62.61 Thu 16:15 Redoutensaal

Correlations between two coherently driven atoms in a cavity — •Marc-Oliver Pleinert[1,2,3], Joachim von Zanthier[1,2], and Girish Agarwal[3,4] — [1]Institut für Optik, Information und Photonik, FAU Erlangen-Nürnberg, 91058 Erlangen, Germany — [2]Erlangen Graduate School in Advanced Optical Technologies (SAOT), FAU Erlangen-Nürnberg, 91052 Erlangen, Germany — [3]Department of Physics, Oklahoma State University, Stillwater, Oklahoma 74078, USA — [4]Institute for Quantum Science and Engineering and Department of Biological and Agricultural Engineering, Texas A&M University, College Station, Texas 77843, USA

The radiative behavior of ensembles of atoms in collective states, i.e., superradiance, has been studied in depth since the seminal paper by Dicke in 1954 (Phys. Rev. 93, 99), where he demonstrated that a group of entangled emitters is able to radiate with increased intensity and modified decay rates in particular directions. Here, we discuss the radiative characteristics and quantum properties of two coherently driven atoms coupled to a single-mode cavity, an ideal setup to investigate the basic aspects of collective behavior. We show that the system is able to exceed the free-space superradiant behavior of two atoms by orders of magnitude, a phenomenon which we call hyperradiance. We also study the phase control of the quantum statistics and find that a quantum version of the negative binomial distribution is able to characterize the photon distribution in the cavity and its quantum features. Our theoretical results could stimulate future experiments as the investigated system can be realized with current technology.

Q 62.62 Thu 16:15 Redoutensaal

Phases of cold atoms interacting via photon-mediated long-range forces — •Francesco Rosati[1], Tim Keller[1,2], Simon B. Jäger[1], and Giovanna Morigi[1] — [1]Universität des Saarlandes, D-66123 Saarbrücken, Germany — [2]Okinawa Institute of Science and Technology Graduate University, Onna-son, Okinawa 904-0495, Japan

When directly pumping an atomic ensemble trapped in a crossed-cavities set up, atomic self-organization can occur via the interaction mediated by the photons. In this work we first derive a Fokker-Planck equation for simulating the atomic evolution in the semi-classical approximation assuming that the photons' time scale for reaching the steady state is much faster than the atomic one.

Then we numerically investigate how this system self-organise in the two cavities; moreover we show that in a two-mode standing-wave cavity the stationary state possesses the same properties and phases of the Generalized Hamiltonian Mean Field model in the canonical ensemble. This model has three equilibrium phases: a paramagnetic, a nematic, and a ferromagnetic one, which here correspond to different spatial orders of the atomic gas and can be detected by means of the light emitted by the cavities.

Q 62.63 Thu 16:15 Redoutensaal

CO_2 laser fabrication of mirrors for cavity QED — •Riccardo Cipolletti, Stefan Häussler, Andrea B. Filipovski, Max Deisböck, and Alexander Kubanek — Institute for Quantum Optics, Ulm University, D-89081 Ulm, Germany

Coupling of solid state quantum emitters to optical microresonators to improve the optical properties of the emitters is a highly innovative field bringing quantum technology applications into reach. For this purpose high quality cavities are crucial. In particular, to achieve high values for cooperativity and Purcell enhancement [1], we need to obtain high finesse and small mode volume.

We show fabrication of cavity mirrors in fused silica using ablation by a CO_2 laser. This method enables small surface roughness and radius of curvature, thus small scattering losses and mode volume. We obtain feedback on the quality and shape of our structures by the use of an interferometer.

[1] D. Hunger *et al* 2010 *New J. Phys.* **12** 065038

Q 62.64 Thu 16:15 Redoutensaal

High- quality- fiber- based microcavity for SiV^- color centers in diamond. — •Richard Waltrich[1], Stefan Häussler[1], Kerem Bray[2], Fedor Jelezko[1], Igor Aharonovich[2], and Alexander Kubanek[1] — [1]Institute for Quantum Optics and Center for Integrated Science and Technology, Ulm University, D-89081 Ulm, Germany — [2]School of Mathematical and Physical Sciences, University of Technology Sydney, Ultimo, New South Wales 2007, Australia

For the realization of quantum repeaters, coherent systems are essential. In the last decades, defects in diamond, especially the negatively charged silicon vacancy center (SiV^-), drew attention due to exceptional optical properties. To overcome issues concerning low rates of spontaneous emitted photons, poor extraction efficiency out of the diamond material, as well as low quantum yield, coupling of the relevant optical dipole transition to the mode of a microcavity is one possibility.

We present a system, consisting of SiV^- centers, located in a thin diamond membrane, coupled to a fiber based microcavity. We aim for enhanced spontaneous emission rates, due to the Purcell effect.

Q 62.65 Thu 16:15 Redoutensaal

Adiabatic flux insertion: growing quantum Hall states of cavity Rydberg polaritons — •David Dzsotjan[1], Peter Ivanov[2], Fabian Letscher[1], Jonathan Simon[3], and Michael Fleischhauer[1] — [1]Department of Physics and Research Center OPTIMAS, University of Kaiserslautern,Kaiserslautern, Germany — [2]Department of Physics, St. Kliment Ohridski University of Sofia, Sofia, Bulgaria — [3]Department of Physics and James Franck Institute, University of Chicago, Chicago, IL, USA

Fractional quantum Hall states, previously discovered in 2D electron gases in solid-state systems, exhibit an intriguing physical behaviour. We propose a scheme that enables to create such states * the so-called Laughlin states * inside a twisted optical ring resonator, using photons dressed with Rydberg interactions. Because of the cavity geometry, these Rydberg polaritons experience an artificial magnetic field leading to Landau levels. Interactions lead to a splitting of the many-body spectrum with gapped states at even fractional fillings. Our aim is to prepare the most stable one, the Laughlin state with filling 1/2 using the growing technique suggested in [1,2]. A key feature of the scheme is the controlled insertion of single photon and magnetic flux quanta into the cavity system. For the insertion of flux quanta we propose and analyze an adiabatic method for transferring external orbital angular momentum from classical light beams to the cavity photons by using light-matter interaction as a mediator. [1] F.Grusdt et al., PRL 113, 155301 (2014) [2] F. Letscher et al., PRB 91, 184302 (2015)

Q 62.66 Thu 16:15 Redoutensaal

X-ray cavity QED beyond the input-output formalism — •Dominik Lentrodt, Kilian P. Heeg, Christoph H. Keitel, and Jörg Evers — MPI für Kernphysik, Heidelberg

The input-output formalism has been one of the main theoretical models in cavity QED, since it allows to describe the atom-cavity dynamics in terms of a few constants, such as resonance energies and decay time scales of the cavity. This is invaluable in understanding the mechanisms behind experimental results, since the constants can be fitted to data. However, in particular in the bad cavity regime or when multiple cavity modes are involved in the dynamics, this method does not always yield a unique explanation of the underlying processes. Indeed the use of input-output formalism for loss-dominated cavities has been debated theoretically and spectroscopic experiments using x-ray cavities doped with Mössbauer nuclei have shown that heuristic extensions to the input-output formalism, such as additional phase shifts, are required in order to successfully model collective Lamb shifts in the system [1,2].

We employ a recently developed method that links ab-initio quantisation to the input-output formalism to predict x-ray spectra in the nuclei-cavity system from the cavity geometry. Within this formalism, the additional phase shifts can now be understood as a multi-mode interference effect, enabled by crucial differences to standard assumptions in the input-output model approach. [1] Röhlsberger, R. et al. (2010). Science, 328, 1248-1251. [2] Heeg, K. P. & Evers, J. (2015). Phys. Rev. A, 91, 063803.

Q 62.67 Thu 16:15 Redoutensaal

Coupling Silicon Vacancy centers in nanodiamond to open acess micro cavities — Andrea Filipovski, •Gregor Bayer, Olaf Zimmermann, and Alexander Kubanek — Institute for Quantum Optics, University of Ulm, Ulm, Germany

For applications such as quantum repeaters or quantum networks efficient spin-photon links are required. One promising system is the negatively charged silicon vacancy (SiV^-) center in diamond which has shown to preserve its good optical properties from bulk in nanodiamonds [1,2]. In order to achieve good coupling between photon field and emitter an optical resonator produced by focussed ion beam milling can be employed. Optimizing the ratio of quality factor over mode volume $\frac{Q}{V}$ is desirable for largest coupling. In our attempt we keep V as small as possible while sustaining a reasonably high Q . Open Fabry-Pérot cavities are particularly attractive since they are tunable and compatible with various emitters. This allows us to examine the interaction between photons and SiV^- centers in nanodiamonds and investigate coupling at cryogenic temperatures.

[1] U. Jantzen et. al., NJP, Vol. 18, 2016 [2] Rogers et. al., in preparation

Q 62.68 Thu 16:15 Redoutensaal

Towards the realisation of an atom trap in the evanescent field of a microresonator — •Luke Masters, Elisa Will, Michael Scheucher, Adele Hilico, Jürgen Volz, and Arno Rauschenbeutel — VCQ, Atominstitut, Stadionallee 2, 1020 Wien, Austria

Whispering-gallery-mode (WGM) resonators guide light by total internal reflection and provide ultra-high optical quality factors in combination with a small optical mode volume. Coupling a single atom to the evanescent field of a WGM microresonator thus allows one to reach the strong coupling regime [1]. Furthermore, such resonators provide chiral light-matter coupling which can be employed for realising novel quantum protocols [2] as well as nonreciprocal quantum devices [3]. However, trapping atoms in the evanescent field of such resonators has not yet been demonstrated, which severely limits the atom-resonator interaction time. We aim to trap single Rubidium atoms in the vicinity of a bottle-microresonator using a standing wave optical dipole trap which is created by retroreflecting a tightly focussed beam on the resonator surface [4]. In order to load atoms into the trap, we employ an FPGA-based electronics which allows us to react in 150 ns to an atom arriving in the resonator field and thus to switch on the dipole trap. We will present first characterisations of our trap and discuss methods for detecting and cooling the atoms in the resonator.

[1] C. Junge et al. Phys. Rev. Lett. 110, 213604 (2013), [2] I. Shomroni et al. Science 345, 903 (2014), [3] M. Scheucher et al. Science 354, 1577 (2016), [4] J. D. Thompson et al. Science 340, 1202 (2013).

Q 62.69 Thu 16:15 Redoutensaal

Classicalization of a scalar quantum field — •Marduk Bolaños, Benjamin A. Stickler, and Klaus Hornberger — Fakultät für Physik, Universität Duisburg-Essen, Duisburg

We present a master equation describing the classicalization of a scalar quantum field. It is based on the back-action of measurements of the amplitude and conjugate momentum of the field.

We show how to solve the master equation using a functional representation of the state operator [1] and study its decoherence dynamics.

[1] R. Graham and H. Haken, Z. Physik A 234, 193 (1970).

Q 62.70 Thu 16:15 Redoutensaal

Bunching and antibunching from a single light source — •Stefan Richter[1], Sebastian Wolf[2], Joachim von Zanthier[1], and Ferdinand Schmidt-Kaler[2] — [1]Institut für Optik, Information und Photonik, Universität Erlangen-Nürnberg, 91058 Erlangen, Germany — [2]QUANTUM, Institut für Physik, Johannes Gutenberg-Universität Mainz, 55128 Mainz, Germany

We have measured the first [1] and second order correlation functions of the light spontaneously emitted from a two ion crystal. The experimental measured $g^{(2)}$ $(t = 0)$ shows bunched or antibunched light, depending on the angle of photon observation and the distance between both ions. The data are compared to a theoretical expectation for the correlation functions using a master-equation approach. In this calculations we take ion motion, the excitation laser power and direction of the driving laser beam into account as well as the observation angle. Future experiments with two detectors at different positions are discussed where again a spatial modulation is predicted [2]. We investigate the feasibility of such experiments under realistic experimental conditions.

[1] S. Wolf et al., Phys. Rev. Lett. **116**, 183002 (2016)
[2] C. Skornia et al., Phys. Rev. A **64**, 063801 (2001)

Q 62.71 Thu 16:15 Redoutensaal

N00N-like Interferences from two Thermal Light Souces — •Daniel Bhatti[1,2], Anton Classen[1,2], Steffen Oppel[1], Raimund Schneider[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

N00N-states have been introduced originally to produce super-resolving interference patterns by use of collective N-photon states propagating along two possible quantum paths [1]. Recent experiments have shown that N independent, incoherently emitting thermal light sources (TLS) can generate similar super-resolving multiphoton interferences when measuring the mth-order intensity correlation function for $m = N$ and if $m-1$ detectors are placed at particular positions [2]. Employing the same $m-1$ fixed detector positions we reveal that N00N-like interferences of arbitrary order can be generated with merely $N = 2$ independent TLS, when measuring higher-order intensity correlation functions with $m \geq 2$ and at least $m-1$ moving detectors. We show that the resulting interference patterns can be interpreted as N00N-like Hanbury Brown and Twiss interferences.

[1] A. N. Boto, et al., Phys. Rev. Lett. 85, 2733 (2000).
[2] S. Oppel, et al., Phys. Rev. Lett. 109, 233603 (2012).

Q 62.72 Thu 16:15 Redoutensaal

Machine Learning to tackle the Entanglement Separability Problem in the Bloch Space — •Klaus Kades[1], Benjamin Classen[1], Matthias Weidemüller[1,2], and Zhen-Sheng Yuan[3] — [1]Physikalisches Institut, Universität Heidelberg, Im Neuenheimer Feld 226, 69120 Heidelberg, Germany — [2]Shanghai Branch, University of Science and Technology of China, 201315 Shanghai, China — [3]Department of Modern Physics, University of Science and Technology of China, 230026 Hefei, China

Determining entanglement and separability is still an open problem for multipartite quantum systems. By transforming the density matrix into the Bloch space, we have a new different access to physical quantities. Lu et al. have shown that entangled and separable states occupy certain regions in this new space (arXiv: 1705.01523). Through analyzing the state space in great depth and by developing a new way to generate random density matrices we can now apply Machine Learning algorithms to identify entangled and separable states.

Q 62.73 Thu 16:15 Redoutensaal

Measurement of Quantum Memory Effects and its Fundamental Limitations — •Matthias Wittemer, Jan-Philipp Schröder, Govinda Clos, Ulrich Warring, Heinz-Peter Breuer, and Tobias Schaetz — Physikalisches Insitut, Albert-Ludwigs-Universität Freiburg

Any realistic quantum system interacts with its environment. Thereby, the open system builds up entanglement and correlations with the environment and exchanges information. Trapped ions offer unique control of internal and external degrees of freedom and are well-suited to engineer closed and open quantum systems. This enables systematic studies of entanglement, decoherence, and thermalization in quantum systems of variable complexity [1]. With our trapped-ion system we measure the flow of information in a closed quantum system and characterize associated memory effects [2]. Thereby, we reveal that the nature of projective measurements in quantum mechanics leads to a nontrivial bias in non-Markovianity measures. We precisely quantify such bias in our trapped-ion system in a regime where numerical simulations are still tractable. Thereby, we challenge current understandings of non-Markovian quantum dynamics by approaching from a most simple showcase [3]. A combination of extended measures for quantum memory effects and our scalable experimental approach can provide a versatile reference, relevant for understanding more complex systems.

[1] G. Clos *et al.*, PRL 117, 170401 (2016), [2] H.-P. Breuer *et al.*, PRL 103, 210401 (2009), [3] M. Wittemer *et al.*, arXiv:1609.04158 (2016)

Q 62.74 Thu 16:15 Redoutensaal

Quantum non-Markovianity with single spins in diamond — •Philipp Vetter[1], Jan Haase[2], Thomas Unden[1], Andrea Smirne[2], Susana Huelga[2], and Fedor Jelezko[1] — [1]Insitute for Quantum Optics, Ulm University, D-89081 Ulm — [2]Institute for Theoretical Physics, Ulm University, D-89081 Ulm

We present an investigation of quantum non-Markovianity with single spins in diamond. We utilize the nitrogen vacancy centre, which enables full control of its electron spin as well as the inherent nitrogen spin. Non-Markovian dynamics are often linked to memory effects inside the environment, which allow a backflow of information into the system of interest [1]. Ramsey experiments on the electron spin are performed to demonstrate precise control of coherence revivals via the population of the nitrogen spin. In addition, we examine the noise floor felt by the electron spin, which originates from further impurities and spins in the diamond lattice. Using Bayesian inference, we estimate the deviation from a true semigroup evolution by polarizing the nitrogen into the non-interacting hyperfine state and a subsequent measurement of the free induction decay.

[1] Rivas, A., Huelga, S. F., & Plenio, M. B. (2014). Quantum non-Markovianity: characterization, quantification and detection. Reports on Progress in Physics, 77(9), 094001.

Q 62.75 Thu 16:15 Redoutensaal

Rotational Decoherence of Molecular Superrotors — •Benjamin A. Stickler[1], Farhad Taher Ghahramani[2], and Klaus Hornberger[1] — [1]Faculty of Physics, University of Duisburg-Essen, Duisburg, Germany — [2]School of Physics, Institute for Research in Fundamental Sciences, Tehran, Iran

A molecule revolving in a thermal gas experiences random collisions with the surrounding gas atoms. We show how these collisions serve to decohere an initial superposition of angular momentum eigenstates if the molecule rotates multiple times during the scattering process. The corresponding Markovian master equation, derived from the quantum linear Boltzmann equation [1], relates the decoherence rate to the microscopic scattering amplitudes of a single collision. We calculate the decoherence rate for nitrogen molecular superrotors and compare it to recent experiments [2].

[1] B. Vacchini, and K. Hornberger, Phys. Rep. 478, 71 (2009) [2] A. A. Milner, A. Korobenko, J. W. Hepburn, and V. Milner, Phys. Rev. Lett. 113, 043005 (2014)

Q 62.76 Thu 16:15 Redoutensaal

Describing a quantum eraser experiment with a symbolic in-out formalism — •Nico Klein[1,2,3], Manuel Daiber[1,2], Lutz Kasper[2], and Matthias Freyberger[1] — [1]Institut für Quantenphysik and Center for Integrated Quantum Science and Technology (IQ^{ST}), Universität Ulm, D-89069 Ulm — [2]Physics Department, University of Education D-73525 Schwäbisch Gmünd — [3]qutools GmbH D-81379 München

Teaching the essential principles of quantum physics to undergraduate students or the general public still remains a challenging task. Here, it is shown how fascinating real-time experiments such as a quantum eraser can contribute to a more phenomenon based and deeper understanding of critical concepts like coherence. An easy to adjust source of single photons and a Michelson interferometer are combined in a modular tabletop setup to perform the experiment. Furthermore, an in-out formalism developed using basic experimental results can be deployed to explain and interpret even these complex quantum optical setups while retaining professional accuracy. Results originate from a cooperation of Ulm University, University of Education Schwäbisch Gmünd and qutools GmbH München.

Q 62.77 Thu 16:15 Redoutensaal

Collective light-matter interaction in the presence of spin-orbit coupling of light — •Zaneta Kurpias, Stefan Walser, Jürgen Volz, and Arno Rauschenbeutel — Vienna Center for Quantum Science and Technology, Atominstitut, TU Wien

In strongly confined light fields, spin-orbit coupling of light leads to an inherent link between the light's local polarization and its propagation direction. This can lead to chirality, i.e. direction dependent interaction between light and matter [1]. In a previous experiment we showed that spin-orbit coupling of light leads to systematic wavelength-scale position errors when imaging subwavelength-scale particles in a microscopy setup. To measure this effect we image a single gold nanoparticle with an optical microscope. Using centroid-fitting techniques, we observed a shift between the emitter's measured and actual position. This difference depends on the polarization of the light emitted by the particle and is comparable to the optical wavelength.

In the next step, we plan to expand our current setup to study light-matter interactions of many particles in the presence of chiral effects. This allows us to explore the influence of spin-orbit coupling on collective effect such as sub- and superradiance.

[1] Nature 541, 473-480, (2017)

Q 62.78 Thu 16:15 Redoutensaal

Coupling cold atoms to a cryogenically cooled optomechanical device — •Philipp Christoph[1], Tobias Wagner[1], Felix Klein[1], Hai Zhong[2], Alexander Schwarz[2], Roland Wiesendanger[2], Klaus Sengstock[1], and Christoph Becker[1] — [1]ZOQ-Center for Optical Quantum Technologies, Luruper Chaussee 149, 22761 Hamburg — [2]Institute of Applied Physics, University of Hamburg, Jungiusstraße 9-11, 20355 Hamburg

Quantum hybrid systems have recently attracted considerable interest due to their prospects of realizing new setups that combine the benefits of several very different quantum systems. We have built an apparatus to optically couple ultracold atoms to a cryogenically cooled membrane oscillator and present work towards preparing both quantum systems in their ground state while they are coupled to each other. Here we characterize and quantify the atom-oscillator coupling, through sympathetic cooling of the membrane by laser cooled cold atoms inside a magneto optical trap. We investigate the sympathetic cooling rate as a function of different experimental parameters of the magneto optical trap and the coupling beam. We compare our data to a simple theoretical model using two coupled harmonic oscillators [1] and find good agreement in certain parameter regimes. For large optical densities of the atomic cloud a more refined model [2] is required to explain the observed heating of the membrane. This work is supported by the DFG via grants of Wi1277/29-1, BE 4793/2-1 and SE 717/9-1.

[1] B. Vogell et al, Phys. Rev. A 87, 023816 (2013)
[2] J. K. Asboth et al, Phys. Rev. A 77, 063424 (2008)

Q 62.79 Thu 16:15 Redoutensaal

Capillary Electrophoresis of Single Proteins via Interferometric Scattering Microscopy — •Mahyar Dahmardeh[1,2], Matthew P. McDonald[1,2], and Vahid Sandoghdar[1,2] — [1]Max Planck Institute for the Science of Light, Staudtstraße 2, D-91058 Erlangen, Germany — [2]Friedrich Alexander University Erlangen-Nuremberg, D-91058 Erlangen, Germany

Electrophoresis has been used as the gold standard assay for studying protein structures and proteomics. However, generally there are certain limitations inherent in the design such as the requirement for a large sample size, long experimental integration times and tedious post processing procedures. All of these make conventional electrophoresis techniques arduous and in some cases impossible to implement. Over the course of the last few years we have developed a label-free optical technique that senses individual nanoparticles and proteins using the interferometric detection of scattered light (iSCAT). iSCAT signals arise from interference between scattered waves and the light backreflected from the microscope cover-glass surface. Since iSCAT operates by way of single protein optical detection, combining it with electrophoresis overcomes the afore mentioned constraints. We have thus developed an electrophoresis based technique compatible with iSCAT-based detection. Initial measurements indicated that this approach is viable and single proteins have been synchronously detected in a prototype iSCAT based apparatus. This work will seek to establish a novel method as a robust, easy-to-use procedure that can markedly supplement existing electrophoretic techniques.

Q 62.80 Thu 16:15 Redoutensaal

Physics and Medicine — •Vahid Sandoghdar — Max-Planck-Institut für die Physik des Lichts, Erlangen

Physicists have a long tradition in developing methods and concepts for the advance of life sciences. In recent decades, however, "medical physics" has been mostly associated with medical "technology" such as methods in radiology, where issues in patient diagnostics and clinical care are addressed. With the recent progress in biophysics and nano-optics, a new era is being born where physicists employ their experimental and theoretical toolboxes to *fundamental* questions in medical research and cell biology. In this poster presentation, I shall discuss some of the current trends in this exciting research area as well as our group's activities within the framework of the newly founded Zentrum für Physik und Medizin in Erlangen.

Q 62.81 Thu 16:15 Redoutensaal

Continuously frequency-tunable diode laser phase locked to an optical frequency comb — •Maximilian Ammenwerth, Lukas Ahlheit, Wolfgang Alt, Deepak Pandey, and Dieter Meschede — Institut für Angewandte Physik, Wegelerstr. 8, D-53115 Bonn

We demonstrate a locking scheme of a diode laser to the spectrum of an optical frequency comb that allows for continuous frequency tuning of the phase locked laser. The heterodyne beat of a comb line and the laser operating at 770 nm is compared to a reference signal from a direct digital synthesizer using a phase-frequency discriminator. The output of this phase-sensitive comparison serves as error signal that is used for applying feedback to laser current and piezo. We compare different scanning schemes that make use of an acousto-optical modulator to scan continuously over comb lines [1,2]. In order to tune the laser frequency over multiple comb lines, fast jumps of the lock point are required. These jumps are analyzed in detail and the phase stability during this process is quantified. We show an application as a complete optical frequency synthesizer based on a microcontroller that allows for setting the optical frequency via an analog voltage or a command line interface.

[1] Will Gunton, Mariusz Semczuk, and Kirk W. Madison. Method for independent and continuous tuning of n lasers phase-locked to the same frequency comb. Optics Letters, 40(18):4372, sep 2015.

[2] John D. Jost, John L. Hall, and Jun Ye. Continuously tunable, precise, single frequency optical signal generator. Opt. Express, 10(12):515-520, Jun 2002.

Q 62.82 Thu 16:15 Redoutensaal

SHG in periodically poled crystals for cooling of relativistic ion beams — •Janika Schwalbach, Daniel Kiefer, and Thomas Walther — Technische Universität Darmstadt, Institut für Angewandte Physik, Laser und Quantenoptik, Schlossgartenstr. 7, 64289, Darmstadt

Fast tunable cw laser systems have many applications. Among others such as laser spectroscopy, cooling of relativistic ion beams is an application of interest [1]. The method is usually employed in addition to electron- and stochastic cooling and uses a laser beam instead to reduce the phase space density of an ion beam circulating in a storage ring. Such a fast tunable cw laser system has been developed and tested successfully cooling C^{3+}-ions [2]. Since then the 257-nm-laser system was further improved. Focus was the LBO based SHG build-up cavity. It is replaced by a single periodically poled crystal based on MgO:PPLN or MgO:PPSLT. Latest results and further aspects will be presented.

[1] U. Schramm, D. Habs. Crystalline ion beams. Progress in Particle and Nuclear Physics 53 (2004), 583-677. [2] T. Beck. Lasersystem zur Kühlung relativistischer C^{3+}-Ionenstrahlen in Speicherringen. Dissertation. Technische Universität Darmstadt (2015).

Q 62.83 Thu 16:15 Redoutensaal

High Power SHG Laser System for 671nm — •Manuel Jäger, Daniel Hoffmann, Thomas Paintner, Wladimir Schoch, Wolfgang Limmer, and Johannes Hecker Denschlag — Institut für Quantenmaterie, Universität Ulm, Deutschland

High-power, stable, single mode lasers have developed into important prerequisites for cold atom production and manipulation. We have built up a narrow-linewidth (< 2 MHz) all-solid-state laser source at 671nm which can be stabilized to the D_2 line of ^{6}Li and provides an output power of 1.1 watt. The construction is based on a design of the group of Christophe Salomon [1,2]. The laser system is based on a ring laser at a wavelength of 1342nm which is frequency-doubled in a cavity.

The ring laser consists of a diode-pumped $Nd:YVO_4$ crystal inside a bow-tie cavity. By using frequency-selective elements we can stabilize the laser for single mode emission and reach an output power of 3-4 watt.

We frequency-double this light using a ppMgO:LN crystal, which features a high conversion efficiency. To increase the second harmonic generation this crystal is placed in an enhancement cavity in bow-tie configuration.

[1] Norman Kretzschmar, Ulrich Eismann, Franz Sievers, Frédéric Chevy and Christophe Salomon, *Opt. Express 25*, 14840-14855 (2017)

[2] U. Eismann, F. Gerbier, C. Canalias, A. Zukauskas, G. Tré, J. Vigué, F. Chevy, C. Salomon, *Appl. Phys. B* 106, 25 (2012).

Q 62.84 Thu 16:15 Redoutensaal

Investigations on a compact low cost molecular iodine laser — Bernd Wellegehausen[1], •Walter Luhs[2], and Mukul Goyal[3] — [1]Institut für Quantenoptik, Leibniz Universität Hannover, Welfengarten 1, 30167 Hannover, Germany — [2]Photonic Engineering Office, Freiburger Str. 33, 79427 Eschbach, Germany — [3]ALKAAD, D-25 Panchsheel Enclave, New Delhi 110017, India

Cw oscillation of molecular iodine on many lines in the range of 557 - 802 nm pumped with a low power common diode pumped and frequency doubled solid state laser (DPSSL) is reported. The DPSSL is temperature stabilized, operates in single frequency and can be tuned by about 2 nm at 532 nm. Operation conditions of this simple and low-cost iodine ring laser will be described and possible applications will be discussed. Parts of this contributions have been published already (Luhs, W., Wellegehausen, B. & Goyal, M. Appl. Phys. B (2017) 123: 125).

Q 62.85 Thu 16:15 Redoutensaal

Phase lock between diode lasers — Stefan Baumgärtner, Manfred Hager, Christoph Raab, Stephan Ritter, and •Stephan Falke — TOPTICA Photonics AG, Lochhamer Schlag 19, 82166 Gräfelfing/München, Germany

Light emitted by cw lasers represents an oscillator with a high quality factor, which is the ratio of the frequency of the light and the linewidth of the laser. For free-running external cavity diode lasers (ECDL) it is typically about one million. By ensuring, in addition, that the absolute frequency of the laser is fixed, one is able to efficiently drive optical transitions of atoms, molecules and ions, e.g. for laser cooling, which relies on the high quality factor of the oscillator.

To stabilize the frequency difference between two lasers, phase locks are commonly applied. This allows for difference frequencies of several GHz and for a synchronization of the two oscillators, which is essential e.g. for addressing narrow two-photon resonances. Other application examples include lasers addressing atoms in high magnetic fields or the stabilization of cw lasers using a frequency comb.

Phase locking two laser fields to each other is possible by utilizing their beat signal, typically recorded with a fast photo-detector, and a fast feedback to one of the lasers. We realized a phase lock between two ECDLs and demonstrate 99% of phase locked light between two ECDL with free running linewidth of 100 kHz. We discuss the requirements on servo and laser, leading to a roll-over of the feedback at more than 1 MHz with commercially available components.

Q 62.86 Thu 16:15 Redoutensaal

Quantitative analysis of a chemical reaction in a microfluidic device using stimulated Raman scattering microscopy — •Peter Fimpel, Martin Josef Winterhalter, and Andreas Zumbusch — Universität Konstanz

Microfluidic devices offer the possibility to monitor reactions with precise control of the reactants ratios. The laminar flow in our device allows us to visualize the reaction kinetics due to pure diffusive mixing. SRS is a perfect tool to quantitatively monitor such processes since it has chemical contrast, is free of non-resonant background and scales linearly with the chemical concentration. This enables us to measure the local concentration with submicrometer spatial resolution and fast acquisition times compared to spontaneous Raman scattering microscopy.

Q 62.87 Thu 16:15 Redoutensaal

Two-color coherent control at a nanotip: from above-threshold photoemission to spectroscopy on a metallic surface — •Ang Li[1], Timo Paschen[1], Michael Förster[1], Michael Krüger[1], Florian Libisch[2], Chritoph Lemell[2], Georg Wachter[2], Thomas Madlener[2], Joachim Burgdörfer[2], and Peter Hommelhoff[1] — [1]Department Physik, Friedrich-Alexander-Universität Erlangen-Nürnberg (FAU), Staudtstr. 1, 91058 Erlangen — [2]Institute for Theoretical Physics, Vienna University of Technology, Wiedner Hauptstr. 8-10/E136, 1040 Wien

Nanotips are routinely used as electron sources in high-resolution electron microscopes [1] and as a basis for studying strong-field phenomena at the surface of solids [2]. When these tips are excited with a fundamental femtosecond laser field and its second harmonic one can coherently control the electronic dynamics on the (sub-) femtosecond time scale. Here, we report on such laser-triggered electron emission studied as a function of pulse delay, optical near-field intensities, dc bias field and final photoelectron energy. Further, a spectroscopy of this coherent signal is presented based on a variation of the wavelength of the two laser fields, revealing a new method of studying the electronic properties of surfaces of different materials. The experimental results are discussed in the framework of quantum-pathway interference supported by local density of states simulations.

[1] A. V. Crewe et al., Rev. Sci. Instrum. 39, 576 (1968).
[2] R. Bormann et al., Phys. Rev. Lett. 105, 147601 (2010).

Q 62.88 Thu 16:15 Redoutensaal

Optical Krypton spectroscopy in magnetic fields — •Peter Zwissler — Universität Tübingen, Germany

We are trying to set up a saturation spectroscopy using a Krypton gas cell. A DC-discharge will excite the atoms in a meta stable state and the spectroscopy laser will drive a transition between this state and another higher excited state. According to theoretical calculations, this set up is highly sensitive to magnetic fields, which can be exploited to build a magnetometer. The poster will give a report about the theory and the current status of the project.

Q 62.89 Thu 16:15 Redoutensaal

Towards high spatial resolution temperature sensing in an optical fiber amplifier — •Alexandra Popp[1,2], Florian Sedlmeir[1,2], Atiyeh Zarifi[3], Birgit Stiller[3], Christian R. Müller[1,2], Ulrich Vogl[1,2], Victor Bock[4], Thomas Schreiber[4], Benjamin J. Eggleton[3], Andreas Tünnermann[4], Christoph Marquardt[1,2], and Gerd Leuchs[1,2] — [1]Max Planck Institute for the Science of Light, Erlangen, Germany. — [2]Department of Physics, University of Erlangen-Nuremberg (FAU), Germany. — [3]School of Physics, University of Sydney, Australia. — [4]Fraunhofer Institute for Applied Optics and Precision Engineering IOF , Jena, Germany.

Extremely powerful lasers are required for various applications in science and industry. The output power of fiber lasers, however, has limits. When the light power inside a single-mode fiber amplifier reaches a certain threshold, the intensity profile out of the fiber starts to become distorted due to so called thermal mode instabilities (TMI) which are not yet fully understood and experimentally difficult to characterize. To investigate TMI, fast in-fiber temperature sensing with a high resolution is required. This has not been achieved yet. We present first measurements towards a setup for high precision in-fiber temperature measurements of an optical fiber amplifier based on Brillouin sensing.

Q 62.90 Thu 16:15 Redoutensaal

Optical modules for dual-species atom interferometry on sounding rockets — •Moritz Mihm[1], Jean Pierre Marburger[1], André Wenzlawski[1], Ortwin Hellmig[6], Klaus Doeringshoff[2], Markus Krutzik[2], Achim Peters[2], Patrick Windpassinger[1], and the MAIUS Team[1,2,3,4,5] — [1]Institut für Physik, JGU Mainz — [2]Institut für Physik, HU Berlin — [3]IQO, LU Hannover — [4]FBH, Berlin — [5]ZARM, Bremen — [6]ILP, UHH Hamburg

More and more quantum technologies are used in extreme environments. The operation outside the laboratory makes high demands on the experiment and especially the laser system regarding miniaturization, power consumption, mechanical and thermal stability. In our systems, optical modules consisting of Zerodur based optical benches with free-space optics are combined with fiber components. Suitability of the technology has been demonstrated in the successful sounding rocket missions FOKUS, KALEXUS and MAIUS.

Here, we report on the optical modules for a quantum gas experiment performing dual-species atom interferometry with BECs on sounding rockets. The modules are used on the one hand to stabilize the laser frequencies and on the other hand to distribute, overlap and switch the laser beams. This includes the overlap and joint fiber coupling of beams at 767 nm and 780 nm in the same polarization state to cool and manipulate atoms of both species simultaneously.

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 numbers 50 WP 1433 and 50 WP 1703.

Q 62.91 Thu 16:15 Redoutensaal

Brillouin and Raman Measurements of Water for Temperature and Salinity Prediction — •Erik Fitzke, Andreas Zipf, David Rupp, and Thomas Walther — TU Darmstadt, Institute of Applied Physics, 64289 Darmstadt

We are working on a LIDAR system for airborne measurements of ocean temperature and salinity. Our goal is to provide oceanographers, marine biologists and meteorologists with a cost-efficient and flexible measurement system capable of depth-resolved acquisition of both parameters in the mixing layer of water down to 100 m depth. We present our recent progress in methods based on Brillouin and Raman scattering.

We continued out preceding work using the Brillouin approach which relies on the analysis of the Brillouin peak shift and peak width for simultaneous measurement of both temperature and salinity. New results for empirical relationships between the variables of interest and the Brillouin peak width will be presented.

As a complementary approach we analyzed the Raman scattering spectrum. By using Partial Least Squares Regression and Artificial Neural Networks we were able to determine temperature and salinity from the spectrum. We will present an overview of the methodology and results for the prediction accuracy of both parameters for the simultaneous analysis of the Raman spectrum.

Q 62.92 Thu 16:15 Redoutensaal

An XUV and soft X-ray split-and-delay unit for FLASH II — •Dennis Eckermann[1], Sebastian Roling[1], Matthias Rollnik[1], Marion Kuhlmann[2], Elke Plönjes[2], Frank Wahlert[1], and Helmut Zachairas[1] — [1]Physikalisches Institut, Universität Münster, Wilhelm-Klemm Straße 10, 48149 Münster, Germany — [2]Deutsches Elektronen Synchrotron, Notkestraße 85, 22607 Hamburg, Germany

An XUV and soft X-ray split-and-delay unit is built that enables time-resolved experiments covering the whole spectral range of FLASH II from $h\nu = 30$ eV up to 2500 eV. With wave front beam splitting and grazing incidence angles a maximum delay of -6 ps $< \Delta$t $< +18$ ps will be possible with a sub-fs resolution. Two different coatings are required to cover the complete spectral range. Therefore, a design that is based on the three dimensional beam path of the SDU at BL2 at FLASH has been developed which allows choosing the propagation via two sets of mirrors with these coatings. A Ni-coating will allow a total transmission on the order of T = 55% for photon energies between 30 eV and 600 eV at a grazing angle $\theta = 1.8°$ in the variable delay line. In the fixed delay line the grazing angle is set so $\theta = 1.3°$. With a Pt-coating a transmission of T $>$ 13 % will be possible for photon energies up to 1500 eV. For a future upgrade of FLASH II the grazing angle can be changed to $\theta = 1.3°$ in order to cover a range up to $h\nu = 2500$ eV.

Q 62.93 Thu 16:15 Redoutensaal

A split-and-delay unit for the European XFEL: Enabling hard x-ray pump/probe experiments at the HED instrument — •Sebastian Roling[1], Karen Appel[2], Peter Gawlitza[3], Harald Sinn[2], Frank Wahlert[1], Ulf Zastrau[2], and Helmut Zachairas[1] — [1]Physikalisches Institut, Univerität Münster, Wilhelm-Klemm Straße 10, 48149 Münster — [2]European XFEL GmbH, Holzkoppel 4, 22869 Schenefeld, Germany — [3]Fraunhofer Institut IWS, Winterbergstraße 28, 01277 Dresden, Germany

For the High Energy Density (HED) instrument at the SASE2 - Undulator at the European XFEL an x-ray split-and-delay unit (SDU) is built covering photon energies from hν = 5 keV up to hν = 24 keV. This SDU will enable time-resolved x-ray pump / x-ray probe experiments as well as sequential diffractive imaging on a femtosecond to picosecond time scale. Further, direct measurements of the temporal coherence properties will be possible by making use of a linear autocorrelation. The x-ray FEL pulses are split by a sharp edge of a silicon mirror (BS) coated with Mo/B_4C and W/B_4C multilayers. Both partial beams then pass variable delay lines. For different wavelengths the angle of incidence onto the multilayer mirrors will be adjusted in order to match the Bragg condition. Because of the different incidence angles, the path lengths of the beams will differ as a function of wavelength. Hence, maximum delays between ±1.0 ps at hν = 24 keV and up to ±23 ps at hν = 5 keV are possible.

Q 62.94 Thu 16:15 Redoutensaal

Wavefront propagation study concerning the influence of non-ideal mirror surfaces inside a split-and- delay unit on the focusability of XFEL-pulses — •Victor Kaercher[1], Sebastian Roling[1], Liobov Samoylova[2], Karen Appel[2], Harald Sinn[2], Frank Siewert[3], Ulf Zastrau[2], and Helmut Zacharias[1] — [1]Physikalisches Institut, WWU Münster, Wilhelm-Klemm Straße 10, 48149 Münster, Germany — [2]European XFEL GmbH, Holzkoppel 4, 22869 Schenefeld, Germany — [3]Helmholtz-Zentrum für Materialien und Energie, Albert-Einstein- Straße 15, 12489 Berlin, Germany

For the High Energy Density (HED) instrument at the SASE2 - Undulator at European XFEL an x-ray split-and- delay unit (SDU) is built covering photon energies from $h\nu = 5$ keV up to $h\nu = 24$ keV. This SDU will enable time-resolved x-ray pump / x-ray probe experiments as well as sequential diffractive imaging on a femtosecond to picosecond time scale. In order to reach intensities on the order of $10^{15}\ W/cm^2$ the XFEL pulses will be focused by means of compound refractive lenses (CRL) to a diameter of $\mathrm{D} = 24\mu m$. The influence of wavefront disturbances caused by height- und slope-errors of the mirrors inside the SDU on the quality of the two focused partial beams is studied by wavefront propagation simulations using the WPG-framework.

Q 62.95 Thu 16:15 Redoutensaal

A rapidly tunable (520 − 680 nm) narrow-bandwidth ps-laser pulse source based on a 1030 nm 80 MHz oscillator — •Lukas Ebner, Martin Josef Winterhalder, and Andreas Zumbusch — Universität Konstanz

In optical spectroscopy the bandwidth of the light directly defines the spectroscopic resolution. We present a method to generate narrow bandwidth ps-laser pulses with a rectangular shape featuring sharp edges in the time domain. To this end we use the soliton fission of a 250 fs laser pulse at 1030 nm in a photonic crystal fiber (PCF) to generate a soliton at around 1300 nm. By frequency doubling this soliton in a periodically poled lithium niobate (PPLN) crystal, we obtain the narrow bandwidth rectangular ps-pulses between (520 − 680 nm). Tunability is given by employing a fan out PPLN with different poling periods.

Q 62.96 Thu 16:15 Redoutensaal

Accurate ultra-broadband amplitude andphase shaping in the visible — •Philipp Hillmann, Alexander Kastner, Jens Köhler, Cristian Sarpe, Hendrike Braun, Arne Senftleben, and Thomas Baumert — Universität Kassel, Institut für Physik und CINSaT, Heinrich-Plett-Str. 40, D-34132 Kassel, Germany

Femtosecond laser pulse shaping is the key technology in quantum control. So far, we were able to demonstrate pulse shaping with sub-cycle temporal accuracy making use of phase and amplitude modulation of femtosecond laser pulses in the infrared spectral region [1]. The experimental demonstration of molecular strong-field control schemes was achieved [2].

Supercontinua exceeding one octave are a prerequisite to generate few-cycle light pulses in the temporal domain. Combining supercontinuum generation spanning from the ultraviolet to near-infrared spectral region with high-throughput prism based pulse shaping [3] opens up the possibility to expand the coherent control techniques to a broader range of electronic systems.

We present the current status of our setup for ultra-broadband amplitude and phase shaping of femtosecond laser pulses characterized by transient grating frequency resolved optical gating.

[1] J. Köhler *et al.*, Optics Express **19** (12), 11638-11653 (2011)
[2] T. Bayer *et al.*, Physical Review Letters **110**, 123003 (2013)
[3] T. Binhammer *et al.*, IEEE **41** (12), 1552-1557 (2006)

Q 62.97 Thu 16:15 Redoutensaal

Towards sub-two-cycle optical pulse compression from Ti:sapphire oscillators — •Philip Dienstbier[1], Takuya Higuchi[1], Francesco Tani[2], Michael Frosz[2], John Travers[3], Philip St. J. Russell[2], and Peter Hommelhoff[1] — [1]Department Physik, Friedrich-Alexander-Universität Erlangen-Nürnberg (FAU), Staudtstraße 1, 91058 Erlangen — [2]Max Planck Institute for the Science of Light, Staudtstraße 2, 91058 Erlangen, Germany — [3]Heriot-Watt University, Edinburgh, EH14 4AS, United Kingdom

Strong-field effects within gases and solids require pulse energies in the μJ to mJ regime achievable with amplified lasers at low repetition rates of a few to hundreds of kHz. For systems such as metal nano-emitters [1] or 2D materials [2] the pulse energies necessary to enter the strong-field regime can be lowered to below 1 nJ due to field enhancement or the special band structure. In this pulse energy range Ti:sapphire oscillators can be used providing pulses as short as two optical cycles with typical repetition rates of 80 MHz. An upgrade of the laser source by further shortening the pulse duration should be beneficial for the study of strong-field effects as the contrast between peaks in the electric-field waveform is enhanced. For this we present a setup to spectrally broaden the output of a Ti:sapphire oscillator by a customized solid-core photonic crystal fiber and a prism-based 4f-pulse compressor with expected compression close to a single optical cycle.

[1] M. Krüger, M. Schenk, M. and P. Hommelhoff, Nature **475**, 78.
[2] T. Higuchi, C. Heide, K. Ullmann, H. B. Weber and P. Hommelhoff, Nature **550**, 224-228.

Q 62.98 Thu 16:15 Redoutensaal

Compression of femtosecond laser pulses using self-phase modulation in dielectric media — •Torben Purz, Sergey Zayko, Ofer Kfir, and Claus Ropers — University of Göttingen, 4th Physical Institute, Göttingen, Germany

The generation of ultrashort laser pulses stimulated the investigation of ultrafast processes at the pico-, femto- and attosecond time scale in physics, chemistry and energy research [1-3]. Pulse compression relies on nonlinear effects, and intense femtosecond pulses are often compressed using a long gas-filled hollow-core waveguide, requiring tight focusing, high beam stability and additional beampath of few meters.

In this work, the compression of femtosecond laser pulses is achieved in solid plates, resulting in a simple, compact and stable setup [4]. We employ self-phase modulation in fused silica and N-BK7 glass to compress 1-2 mJ pulses from a Ti:Sapphire amplifier of 43 fs pulse duration, down to 20 fs. Numerical simulations indicate that self-phase-modulation, self-steepening and intrapulse Raman scattering determine the final pulse shape, in good agreement with the experimental data. We investigate the coupled group-delay dispersion and third-order dispersion dependence of the spectral broadening. The compressed pulses are applied for second harmonic and high-harmonic generation, showing a substantial increase of the harmonics flux.

[1] Zewail *et al.*, Science **266**, 1359-1364 (1994)
[2] Gattass *et al.*, Nature Photonics **2**, 219-225 (2008)
[3] Ditmire *et al.*, Nature **398**, 489-492 (1999)
[4] Kung *et al.*, Optica **6**, 400-406 (2014)

Q 62.99 Thu 16:15 Redoutensaal

Novel laser-driven photonic structures for high efficiency electron acceleration — •Peyman Yousefi, Joshua McNeur, Martin Kozák, Norbert Schönenberger, and Peter Hommelhoff — Department Physik, Friedrich-Alexander-Universität Erlangen-Nürnberg (FAU), Staudtstr. 1, 91058 Erlangen

Dielectric laser acceleration (DLA) has proven to be a reliable concept for future table-top particle accelerators. In DLA, electrons traverse the accelerating near fields excited by ultrafast lasers impinging on dielectric nanostructures. Acceleration of electrons with varying energies has been demonstrated with gradients approaching 1 GeV/m [1]. To realize longer interaction length over multiple stages, structures that efficiently convert the incoming laser field into the accelerating mode are critical. A dual pillar grating, described here, has proven to be a good candidate for high efficiency acceleration. Further, it provides a proper symmetry in the field profile and reduces the deflecting forces. Here we present electron acceleration with a dual pillar silicon grating using a distributed Bragg reflector (DBR). We address the effect of DBR on the acceleration gradient and also report on a new geometry of dual pillars for higher acceleration gradients.

1.England, R. J.et al. Dielectric laser accelerators. Rev.Mod. Phys. 86, 1337 (2014).

Q 62.100 Thu 16:15 Redoutensaal

Numerical studies of electron pulse broadening in laser-triggered sources — •Johannes Illmer, Joshua McNeur, Martin Kozák, Norbert Schönenberger, and Peter Hommelhoff — Department Physik, Friedrich-Alexander-Universität Erlangen-Nürnberg (FAU), 91058 Erlangen

In the field of ultrafast physics, femtosecond electron pulses have proven to be a useful tool to study ultrafast phenomena in condensed matter systems [1]. One way of generating these short electron pulses is the laser-triggering of an electron source, designed for DC beams, with femtosecond UV laser pulses. Due to effects such as space charge, trajectory differences and dispersion in vacuum, the initial temporal profile of the electron pulses becomes broadened, limiting the achievable resolution. We present numerical studies of this effect in order to investigate the pulse broadening behavior of laser-triggered electron sources. The electrostatic fields of the electron gun are calculated with a Poissonian field solver. Trajectory and space charge effects are calculated via a 5th order Runge-Kutta algorithm. A first validation of this method was shown by correlating experimental results with a numerical study of the electron pulse broadening. Furthermore, we discuss investigations of new source configurations to identify setups that minimize such broadening. A special focus is the development of new source types for application in dielectric laser accelerators (DLA)[2].

[1] A. H. Zewail and J. M. Thomas, "4D Electron Microscopy: Imaging in Space and Time", Imperial College Press (2010)

[2] R. Joel England et al., Rev. Mod. Phys. 86, 1337 (2014)

Q 62.101 Thu 16:15 Redoutensaal

Spatiotemporal characterization of laser filaments in noble gases — •Christoph Jusko[1], Lana Neoricic[2], Shiyang Zhong[2], Miguel Miranda[2], Cord Arnold[2], and Milutin Kovacev[1] — [1]Institut für Quantenoptik, Leibniz Universität Hannover, Welfengarten 1, 30167 Hannover, Deutschland — [2]Division of Atomic Physics, Lund University, Professorsgatan 1, 223 63 Lund, Schweden

Laser filaments in noble gases show highly nonlinear temporal and spatial dynamics along the propagation direction, e.g. leading to high peak intensities, spectral broadening and interesting effects like self-shortening of femtosecond laser pulses. We present an experimental approach for a comprehensive, propagation-position-dependent study of the temporal as well as the spatial filament dynamics taking place in argon. Later, insights about the dynamics could support pump-probe studies on noble gas filaments in order to detect Kramers-Henneberger atoms.