Q 62: Poster: Quantum Optics and Photonics III

Time: Thursday 17:00–19:00 Location: C/Foyer

Q 62.1 Thu 17:00 C/Foyer

Towards imaging of single Rydberg Atoms — •Vladislav Gavryusev, Georg Günter, Gerhard Zuern, Miguel Ferreira-Cao, Giulia Faraoni, Hanna Schempp, Shannon Whitlock, and Matthias Weidemüller — Physikalisches Institut, Universitat Heidelberg, Im Neuenheimer Feld 226, 69120 Heidelberg, Germany

Electronically highly excited (Rydberg) atoms constitute a system with long range interactions which allows to study many intriguing phenomena, ranging from quantum non-linear optics to dipole-mediated energy transport.

To optically image Rydberg atoms we use the interaction enhanced imaging technique [1] which exploits interaction-induced shifts on highly polarizable excited states of probe atoms, that can be spatially resolved via an electromagnetically induced transparency resonance. With this tool we observed by monitoring the Rydberg distribution the migration of Rydberg electronic excitations, driven by quantum-state changing interactions [2]. To push this technique to the level of individual Rydberg atom detection we developed a simple analytic Hard-Sphere model for light propagation through an atom cloud that takes into account interaction effects and technical noise sources. The model predicts a signal to noise ratio > 1 and agrees with numerical non linear light propagation simulations. We will present our progress towards the observation of individual Rydberg atoms which would allow to study the spatial and temporal dynamics of the system.

[1] G. Günter et al., Phys. Rev. Lett. 108, 013002 (2012)
[2] G. Günter et al., Science 342, 954 (2013)

Q 62.2 Thu 17:00 C/Foyer

Dipolar exchange in interacting Rydberg gases — •Miguel Ferreira-Cao, Georg Günter, Hanna Schempp, María M. Valado, Vladislav Gavryusev, Gerhard Zürn, Shannon Whitlock, and Matthias Weidemüller — Physikalisches Institut, Universität Heidelberg, Im Neuenheimer Feld 226, 69120 Heidelberg, Germany

Dipolar exchange interactions play an important role in diverse systems ranging from polar molecules to molecular aggregates, light-harvesting complexes or quantum dots [1]. Ultracold Rydberg atoms offer an ideal system to study dipolar energy transport under the influence of a controlled environment [2].

We have performed measurements of microwave driven Rabi oscillations between Rydberg states with angular momentum state s and p in which interactions lead to reduced contrast for high Rydberg densities. This system constitutes a realization of a XY spin model with long-range and anisotropic spin-spin interactions [3,4]. The build-up of correlated phases of the spin distribution is an important aspect under investigation. Applying tomographic methods, future measurements can reveal the time-dependent properties of the many-body state.

[1] B. Yan et al., Nature 501, 521-525 (2013)
[2] G. Günter et al., Science 342, 954 (2013)
[3] D. Maxwell et al., Phys. Rev. Lett. 110, 103001 (2013)
[4] D. Barredo et al., arXiv:1408.1055 (2014)

Q 62.3 Thu 17:00 C/Foyer

Rydberg dressing of ultracold Potassium atoms via electromagnetically induced transparency — •Christoph Schweiger, Nils Pehoviak, Stephan Helmrich, Alda Arias, and Shannon Whitlock — Physikalisches Institut, Universität Heidelberg, Im Neuenheimer Feld 226, 69120 Heidelberg

We aim to use laser dressing of Rydberg states of ultracold potassium atoms to create and study novel strongly-correlated quantum gases with long-range interactions. Rydberg dressing, i.e. the small admixture of a Rydberg state to the ground state [1] can be realised via a single-photon transition or a two-photon transition in a three-level ladder scheme. We use a two-photon transition in an electromagnetically induced transparency (EIT) configuration to excite potassium-40 atoms to Rydberg states. The Rydberg state admixture and the lifetime of the dressed-states can be controlled by the ratio of the Rabi frequencies of the laser fields. We will describe a high-power narrow-linewidth laser system used to produce up to 2 W at a wavelength of 460 nm. It is stabilised using spectroscopy of Rydberg states using an EIT resonance using thermal atoms in a vapor cell. We will report our first experiments on EIT spectroscopy of potassium atoms, and discuss the prospects for creating long-range interacting fermionic quantum gases via Rydberg dressing.

[1] Balewski, J.B. et al. "Rydberg dressing: Understanding of collective many-body effects and implications for experiments", arXiv:1312-6346, 2013

Q 62.4 Thu 17:00 C/Foyer

Rydberg quantum optics in ultracold gases — •Ivan Mirgorodskiy, Hannes Gorniaczyk, Christoph Tresp, Sebastian Weber, and Sebastian Hofferberth — 5. Physikalisches Institut, Universität Stuttgart, Germany

Mapping the strong interaction between Rydberg excitations in ultracold atomic ensembles onto single photons via electromagnetically induced transparency enables manipulation of light on the single photon level. We report the realization of a free-space single-photon transistor, where a single gate photon controls the transmission of more than 60 source photons. We show that this transistor can also be operated as a quantum device, where the gate input state is retrieved from the medium after the transistor operation. In addition, we demonstrate general theoretical techniques for the dynamic description of Rydberg pair state admixture at nonzero interaction angles with respect to the quantization axis. This model explains our experimental observation of dipolar dephasing of D-states.

Q 62.5 Thu 17:00 C/Foyer

Towards a single-photon source based on Rydberg FWM in thermal microcells — •Fabian Ripka, Yi-Hsin Chen, Robert Löw, and Tilman Pfau — 5. Physikalisches Institut Universität Stuttgart, Stuttgart, Deutschland

Photonic quantum devices based on atomic vapors at room temperature combine the advantages of atomic vapors being intrinsicly reproducible as well as semiconductor-based concepts being scalable and integrable. One key device in the field of quantum information are single-photon sources. A promising candidate for realizing an on-demand single-photon source relies on the combination of two atomic effects, namely four-wave mixing (FWM) and the Rydberg blockade.

Coherent dynamics to Rydberg states has been demonstrated in thermal vapor cells on nanosecond timescales [1] and van-der-Waals interaction has been observed [2], where the interaction strength exceeds the energy scale of thermal motion and is thus strong enough to enable quantum correlations. Subsequently, we observed both coherent dynamics and effects of dephasing due to Rydberg-Rydberg interaction also in a pulsed FWM scheme [3]. Both are essential effects for building up a single-photon source. As the next step, we are about to reduce the excitation volume towards below the Rydberg interaction range by use of high-NA optics and spatial confinement. First investigations on effects of the confinement on the FWM signal will be shown.

[1] Huber et al., PRL 107, 243001 (2011)
[2] Baluktsian et al., PRL 110, 123001 (2013)
[3] Huber et al., PRA 90, 053806 (2014)

Q 62.6 Thu 17:00 C/Foyer

Dynamical Mean-Field Theory of Rydberg-dressed quantum gases in optical lattices — •Andreas Geissler[1], Mathieu Barbier[1], Ivana Vasic[2], and Walter Hofstetter[1] — [1]Goethe Universität, Frankfurt a. M., Germany — [2]University of Belgrade, Belgrade, Serbia

Recent experiments have shown that Rydberg-dressed quantum many body systems with large numbers of Rydberg excitations in an optical lattice are within reach. We have studied these strongly correlated systems for the bosonic case both within the Gutzwiller approximation (GA) and in a real-space bosonic extension of Dynamical Mean-Field Theory (RB-DMFT) for a two-species lattice Hamiltonian. While RB-DMFT becomes computationally demanding for high lattice fillings, the GA still allows for a thorough investigation of the phase space. We find new exotic quantum phases of lattice commensurate order, giving rise to a devil's staircase in the filling as a function of the chemical potential, long-range interaction and Rabi laser detuning. With increasing hopping, a nonzero condensate fraction starts to emerge, which can coexist with the spatial density-wave order, giving rise to a series of supersolid phases. Spontaneously broken lattice symmetries imply an anisotropic superfluid fraction. We obtain a rich phase diagram in our simulations for the chosen range of experimentally relevant parameters.

Q 62.7 Thu 17:00 C/Foyer

Laser System for Two-Photon Rydberg Excitation of Trapped Strontium Ions — •Fabian Pokorny[1], Gerard Higgins[1], Christine Maier[2], Johannes Haag[1], Florian Kress[1], Yves Colombe[1], and Markus Hennrich[1] — [1]Institut für Experimentalphysik, Universität Innsbruck, Austria — [2]Institut für Quantenoptik und Quanteninformation, Innsbruck, Austria

Trapped Rydberg ions form a novel physical system, combining the technologies of neutral Rydberg atoms and trapped ions [1]. Such a system promises interesting Rydberg physics, since the ions are trapped in an oscillating electric field [1-3].

Here we present our progress realising such a system of trapped Rydberg ions. In particular, we show the laser system we want to use for the two-photon Rydberg excitation of strontium ions trapped in a linear Paul trap. The photons involved in this process have wavelengths of 243nm and 305 - 310nm. The highly tunable UV laser light at 305nm is generated by sum-frequency generation and subsequent second harmonic generation. To overlap both laser beams we use photonic-crystal fibers. Hydrogen-loading the fibers successfully cures colour centres and prevents degeneration [4]. With achromatic lenses a focus of roughly $10\mu m$ is achieved on the ions for both wavelengths.

[1] M. Müller, et al., New J. Phys. **10**, 093009 (2008)
[2] F. Schmidt-Kaler, et al., New J. Phys. **13**, 075014 (2011)
[3] W. Li, and I. Lesanvoski, Appl. Phys. B, **117**, 37 (2014)
[4] Y. Colombe, et al., Opt. Express, **22**, 19783 (2014)

Q 62.8 Thu 17:00 C/Foyer

Interaction Effects and Collisional Processes in Mesoscopic Rydberg Driven Ensembles — •Torsten Manthey, Thomas Niederprüm, Oliver Thomas, Tobias M. Weber, and Herwig Ott — Universität Kaiserslautern

We study the longtime behavior of ultracold mesoscopic atomic ensembles excited to Rydberg P-states. To this purpose, we use a scanning electron microscope to tailor arbitrary density distributions and an ultraviolet laser beam to excite Rydberg atoms. This allows for the investigation of interaction effects between multiple Rydberg atoms as well as a Rydberg atom and a ground state atom. In this context, we have created an isolated ultracold atomic 87Rb ensemble spatially confined in the blockade volume of a Rydberg atom, a so-called superatom. In this volume only one Rydberg excitation is possible as a result of the Rydberg blockade, where all other atoms are shifted out of resonance due to the strong dipole dipole interaction. Furthermore we can study the creation of molecular ions, produced by a transport mechanism based on the scattering of the Rydberg electron with a ground state atom and the interaction of this atom with the ionic core. Finally we show that the presence of an electron beam during the excitation of atoms into Rydberg states has a massive effect on the excitation probability, which is due to l-changing collisions of the Rydberg atoms with the electron beam.probability, which is due to l-changing collisions of the Rydberg atoms with the electron beam.

Q 62.9 Thu 17:00 C/Foyer

Rydberganregung von $^{40}Ca^+$ mit Vakuum-Ultraviolettem-Laserlicht — •Patrick Bachor[1,2], Matthias Stappel[1,2], Jochen Walz[1,2], Thomas Feldker[1] und Ferdinand Schmidt-Kaler[1] — [1]QUANTUM, Institut für Physik, Universität Mainz, Staudingerweg 7, D-55128 Mainz, Germany — [2]Helmholtz-Institut Mainz, D-55099, Germany

Werden Ionen in einem kalten, gefangenen Coulomb-Kristall in hoch angeregte Rydbergzustände gebracht, ergeben sich interessante neue Möglichkeiten für die Quanteninformationsverarbeitung. Zum einen können aufgrund des für Rydbergzustände modifizierte Fallenpotential spezielle Vibrationsmoden designed werden, zum anderen sind schnelle Verschränkungsoperationen mittels Dipol-Dipol-Wechselwirkung möglich. Wir beobachten die Anregung von $^{40}Ca^+$ Ionen aus dem metastabilen $3D_{3/2}$ Zustand mit Vakuum-Ultraviolettem-Laserlicht(VUV) in den Rydbergzustand $54P_{1/2}$ oder $52F_{5/2}$. Für diesen Übergang wurde eine Wellenlänge von 122,04192 nm ermittelt. Wir präsentieren erste Ergebnisse der Rydbergspektroskopie an einzelnen $^{40}Ca^+$ Ionen, und diskutieren den Einfluss des dynamischen Quadrupolfeldes der Paulfalle auf die beobachtete Resonanzlinie. Zudem stellen wir die Weiterentwicklung des Experimentes bezüglich der VUV-Erzeugung und -Stabilisierung sowie der Ionenfalle dar.

Q 62.10 Thu 17:00 C/Foyer

Collective Rabi oscillations and progress towards Rydberg dressing — •Peter Schauss[1], Johannes Zeiher[1], Sebastian Hild[1], Jae-yoon Choi[1], Tommaso Macri[2], Rick van Bijnen[2], Thomas Pohl[2], Immanuel Bloch[1,3], and Christian Gross[1] — [1]Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Straße 1, 85748 Garching, Germany — [2]Max-Planck-Institut für Physik komplexer Systeme, Nöthnitzer Straße 38, 01187 Dresden, Germany — [3]Fakultät für Physik, Ludwig-Maximilians-Universität München, Schellingstraße 4, 80799 München, Germany

Rydberg atoms open new perspectives for long-range correlated many-body states due to their strong van der Waals interactions.

In one experiment, we investigate Rydberg gases in the fully dipole blockaded regime and observe coherent collective Rabi oscillations for ensembles from a single up to 180 atoms. We optically excite the Rydberg atoms and detect them with submicron resolution, allowing to gain information about the local structure of the prepared states, especially where the fully-blockaded assumption breaks down.

In a second experiment, we implemented single-photon excitation to rubidium Rydberg P-states via an ultra-violet transition at 297 nm. We report on the observation of correlated loss due to the P-state Rydberg-Rydberg interactions and first experiments on Rydberg dressing potentials.

Q 62.11 Thu 17:00 C/Foyer

Controlled interactions between optical photons stored as Rydberg polaritons — •Hannes Busche, Simon W. Ball, Teodora Ilieva, Paul Huillery, Daniel Maxwell, David Paredes-Barato, David J. Szwer, Matthew P. A. Jones, and Charles S. Adams — Joint Quantum Centre (JQC) Durham-Newcastle, Department of Physics, Durham University, South Road, Durham, DH1 3LE, United Kingdom

We are using electromagnetically induced transparency to store photons as Rydberg excitations in a cold atom cloud in order to map their strong and long-ranged dipolar interactions onto the optical field and introduce effective interactions at the single photon level. The application of an external microwave field [1] allows control of the interaction strength, manifesting itself in a modification of the retrieved photon statistics [2].

Recently, we completed a new experimental apparatus that will give us the ability to store single photons in individually addressable sites. In this setup, we aim to study interactions between stored photons in spatially separated channels and explore applications such as the implementation of a universal quantum gate for photonic qubits [3].

[1] D. Maxwell et al., Phys. Rev. Lett. 110, 103001 (2013).
[2] D. Maxwell et al., Phys. Rev. A 89, 043782 (2014).
[3] D. Paredes Barato and C. S. Adams, Phys. Rev. Lett. 112, 040501 (2014).

Q 62.12 Thu 17:00 C/Foyer

Nonlinear nonlocal response of thermal Rydberg atoms — •Lida Zhang and Jörg Evers — Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, D-69117 Heidelberg

A novel approach is proposed to describe light propagation through thermal Rydberg atoms. Under the crucial approximation that the temporal variation in the dipole-dipole interactions due to atomic motions can be neglected in an ensemble average, an analytical form can be obtained for the nonlocal nonlinear atomic response of the thermal medium. Based on this analytical result, we find that in the the near-resonant regime the nonlinear absorption for the probe field is weakened as the temperature increases. On the contrary, when the laser fields are far-off resonant, the nonlocal nonlinear dispersion remains almost unchanged while the nonlocal nonlinear absorption is initially enhanced and then weakened as the temperature grows. Consequently, the modulational instability (MI) is initially suppressed, and then strengthened with increasing temperature. In contrast to purely dispersive cold nonlinear media, counterintuitively, we find that in absorptive nonlinear media each wave component exhibits the MI effect, which however competes with the nonlocal nonlinear absorption, and eventually is suppressed.

Q 62.13 Thu 17:00 C/Foyer

Towards splitting single atom trajectories over macroscopic distances — •Gautam Ramola, Carsten Robens, Jonathan Zopes, Wolfgang Alt, Dieter Meschede, and Andrea Alberti — Institut für Angewandte Physik, Universität Bonn

Ultracold atoms in optical lattices are versatile and robust systems allowing unprecedented control over atomic states for wide-ranging applications in quantum optics and quantum information processing. Recent developments in state-dependent transport offer advanced control over the quantum dynamics of single particles, e.g., as required for a single atom interferometer[1]. We apply optimal control theory to realize robust coherent transport of atoms over large distances. This holds promise for coherently splitting atoms up to macroscopic distances at the millimeter scale. Key components in the realization of such macroscopic state-dependent transport are two optical phase-locked loops(PLL). I will present recent progress in the development of a versatile vector generator, using a DDS chip interfaced with a FPGA controller for real-time fast programming, which will produce the RF reference signal in the PLL servo system enabling us to program complex transport sequences in real-time.

[1] A. Steffen et al. Digital atom interferometer with single particle control on a discretized space-time geometry. PNAS 109, 9770-9774 (2012)

Q 62.14 Thu 17:00 C/Foyer

A High-Speed Imaging System and a Two-Colour Magneto-Optical Trap for Discrete-Time Quantum Walks — •Volker Schilling, Stefan Brakhane, Stanislav Shestovy, Felix Kleissler, Wolfgang Alt, Andrea Alberti, and Dieter Meschede — Institut für Angewandte Physik der Universität Bonn, Wegelerstr. 8, 53115 Bonn

We report on a vacuum compatible imaging system for fluorescence detection and coherent manipulation of neutral Cs atoms in single sites of a two-dimensional state-dependent optical lattice with a diffraction limited resolution of $\sim 560\,\mathrm{nm}$. The imaging system is based on an in-house designed objective featuring a numerical aperture of 0.92 at a working distance of $150\,\mu\mathrm{m}$. It is placed inside a low-birefringence ultra-high vacuum glass cell. Experimental techniques for the characterization of high numerical aperture objectives including field of view measurements will be shown.

We will further present first results on the realization of a two-colour magneto-optical trap in front of the objective. The replacement of the D2 line light of Cs by the D1 line along the optical axis of the objective will enable us to effectively cool the atoms during illumination while suppressing stray light.

The high-resolution imaging system in combination with a state-dependent lattice will enable us to simulate complex physical phenomena, for instance, artificial magnetic fields [1] by means of discrete-time quantum walks in two dimensions.

[1] M. Genske, *et al.*, Phys. Rev. Lett. **110**, 190601 (2013).

Q 62.15 Thu 17:00 C/Foyer

Light shifts and mechanical dynamics of single Rb atoms in a deep two-dimensional optical lattice — •Matthias Körber, Andreas Neuzner, Olivier Morin, Stephan Ritter, and Gerhard Rempe — Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Str. 1, 85748 Garching

Single neutral atoms in an optical cavity are a powerful experimental system that allows for a high degree of control over light-matter interaction. Optical lattices are commonly used to trap and tightly confine the atoms. Besides the obvious influence on the mechanical motion, optical trapping influences the internal degrees of freedom of trapped atoms as well. Here, we experimentally study mechanical dynamics and we find strong implications for optical cooling strategies. Furthermore, we observe the onset of decoupling of nuclear spin from the hull's angular momentum and find good agreement between experiment and a theoretical model. We like to emphasize that instead of a mere curiosity our findings are actually high relevance for everyday lab work.

Q 62.16 Thu 17:00 C/Foyer

Ultracold erbium atoms in a quasistatic optical dipole trap — •Daniel Babik, Henning Brammer, Jens Ulitzsch, and Martin Weitz — Institut für Angewandte Physik, Wegelerstraße 8, 53115 Bonn

The erbium atom has a $4f^{12}6s^2\ {}^3H_6$ electronic ground state with a large angular momentum of $L = 5$. On the other hand alkali atoms, which are commonly used in optical lattice experiments, have a spherical symmetric ($L = 0$) S-ground state configuration, for which in far detuned laser fields with detuning above the upper state fine structure splitting the trapping potential is determined by the scalar electronic polarizability. For an erbium atomic quantum gas with its $L > 0$ electronic ground state, the trapping potential also for far detuned dissipation-less trapping laser fields becomes dependent on the internal atomic state (i.e. spin).

We have loaded erbium atoms from a magneto-optical trap driven by the blue 400.91 nm transition into a quasistatic optical dipole trap generated by a focused CO_2-laser beam with a wavelength near $10{,}6\,\mu\mathrm{m}$. Evaporative cooling of erbium atoms in such a trap was demonstrated. 12000 erbium atoms where cooled down to approximately $2\,\mu\mathrm{K}$ temperature in the quasistatic dipole trap. The achieved atomic phase-space density presently reaches 1.8×10^{-4}. Recent experimental progress will be discussed.

Q 62.17 Thu 17:00 C/Foyer

Molecular spectroscopy of ultracold ^{23}Na^{40}K — •Frauke Seesselberg[1], Nikolaus Buchheim[1], Zhenkai Lu[1], Tobias Schneider[1], Immanuel Bloch[1,2], and Christoph Gohle[1] — [1]Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Straße 1, 85748 Garching, Germany — [2]Ludwig-Maximilians-Universität, Schellingstraße 4, 80799 München, Germany

Ultracold quantum gases with long-range dipolar interactions promise exciting new possibilities for quantum simulation of strongly interacting many-body systems.

We have constructed an experimental apparatus aiming to create ultracold groundstate ^{23}Na^{40}K molecules. To obtain molecules in their absolute vibrational, rotational and hyperfine ground state we want to implement stimulated Raman adiabatic passage (STIRAP), which is a two photon process capable of transferring weakly bound Feshbach molecules via an intermediate, excited molecular state to the ground state with high efficiency.

Intermediate molecular levels with sufficiently large transition matrix elements to both the initial and the final state can be found in the d/D-potentials of ^{23}Na^{40}K. Here we will present recent spectroscopy results regarding Feshbach molecules and photoassociation towards implementing STIRAP.

Q 62.18 Thu 17:00 C/Foyer

Creation of Fermi-Bose mixture of ^{6}Li and ^{133}Cs at ultracold temperatures — •Stephan Häfner[1], Juris Ulmanis[1], Rico Pires[1], Eva D. Kuhnle[1], Matthias Weidemüller[1], and Eberhard Tiemann[2] — [1]Physikalisches Institut, Ruprecht-Karls Universität Heidelberg, Im Neuenheimer Feld 226, 69120 Heidelberg, Germany — [2]Institut für Quantenoptik, Leibniz Universität Hannover,Welfengarten 1, 30167 Hannover, Germany

An ultracold Fermi-Bose mixture of ^{6}Li and ^{133}Cs is an ideal system for the study of Efimov's scenario, which predicts an infinite series of geometrically spaced three-body bound states in the limit of resonant pairwise interactions. Due to the large mass imbalance the universal scaling factor is reduced to 4.9, which makes the observation of a series of resonances feasible. Recently we observed two consecutive Efimov resonances close to a broad Feshbach resonance at temperatures of 400 nK [1]. In this poster we present the route to obtain temperatures below 100 nK for this strongly mass imbalanced mixture involving the combination of optical dipole traps at different wavelengths for an optimized species selective trapping potential. In addition, we measure the binding energy of the least bound molecular state near the broad LiCs Feshbach resonances and compare them to a coupled-channels calculation, which extends our previous analysis [2] of the LiCs scattering properties.

[1] R. Pires et al., PRL 112, 250404 (2014)
[2] R. Pires et al., PRA 90, 012710 (2014)

Q 62.19 Thu 17:00 C/Foyer

Anomalous diffusion of a single atom in a lattice in presence of an external force — •Farina Kindermann, Michael Bauer, Felix Schmidt, Tobias Lausch, Daniel Mayer, and Artur Widera — TU Kaiserslautern, FB Physik, Erwin-Schrödinger-Str. 46, 67663 Kaiserslautern

The dynamics of particle systems is often modelled by a classical random walk, leading to Gaussian statistics. But in the last decades it has been shown that systems exist, where rare but often long ranged events dominate the diffusion dynamics. These systems are described by heavy-tailed distributions such as Levy statistics. Here we present a setup, where a single neutral atom performs a random walk in a 1D lattice, when it is driven by an optical molasses and hence undergoes frequently photon scattering. We analyze the single step length distribution and the diffusion coefficient, which can both show a significant deviation from the expected Gaussian distribution.

Q 62.20 Thu 17:00 C/Foyer

A Species-Selective Optical Conveyor Belt Lattice for Neutral Cesium Atoms — •Felix Schmidt[1,2], Daniel Mayer[1,2], Michael Bauer[1], Farina Kindermann[1], Tobias Lausch[1], and Artur Widera[1,2] — [1]Department of Physics and Research Center OPTIMAS, University of Kaiserslautern, Germany — [2]Graduate School Materials Science in Mainz, Gottlieb-Daimler-Strasse 47, 67663 Kaiserslautern, Germany

For experiments with binary mixtures of ultracold quantum gases the ability to control the position as well as the motional states of both atomic species independently is desired. In our experiment, aiming at deterministic doping of ^{87}Rubidium (Rb) Bose-Einstein condensates (BEC) with single Cesium (Cs) atoms, we transport the Cs atoms using a conveyor belt formed by a one-dimensional optical lattice.

The lattice is tuned to a wavelength in between the D_1 and D_2 lines of Rb, where the optical dipole potential for Rb vanishes and thereby a species-selective lattice in the so-called tune-out scheme is realized. By slightly detuning the frequency of the counterpropagating beams, that form the lattice, we can carry the Cs over hundreds of micrometres with high reproducability and precision.

Here we report on the characterization of our conveyor belt showing both the deterministic transport of single Cs atoms, and the investigation of the lattice's influence on the Rb BEC.

Q 62.21 Thu 17:00 C/Foyer

Arbitrary optical traps with spatial light modulators — •Marvin Holten, Puneet Murthy, André Wenz, Gerhard Zürn, and Selim Jochim — Physikalisches Institut, Im Neuenheimer Feld 226, 69120 Heidelberg

One of the main challenges of quantum simulation is engineering the Hamiltonian. A particularly interesting approach towards realizing this goal has been the use of ultracold quantum gases trapped in tailor-made optical potentials. In this poster we show how such potentials can be created by using a phase-modulating Spatial Light Modulator. We investigate numerical methods to address the difficult problem of finding the correct phase pattern to obtain a desired intensity distribution. Furthermore, we develop algorithms to measure and correct aberrations introduced by the experimental setup. We present results of intensity patterns created with light in an actual setup and discuss the implementation of these techniques in ultracold atom experiments.

Q 62.22 Thu 17:00 C/Foyer

A Hybrid Microscopic Microwave Sensor — •Daniel Weller[1], Georg Epple[2], Christian Veit[1], Kathrin S. Kleinbach[1], Tilman Pfau[1], and Robert Löw[1] — [1]5. Physikalisches Institut, Universität Stuttgart, Stuttgart, Germany — [2]Max Planck Institute for the Science of Light, Erlangen, Germany

Over the past few years, the usage of atomic vapors has become more and more relevant for applications in quantum technology. Our research focuses on the combination of atomic physics with fiber technology: by enclosing thermal vapor inside hollow core optical fibers, an in-line interaction region between atoms, light and external fields can be realized in miniaturized devices.

Our goal is to exploit the exceptional high sensitivity of Rydberg atoms in combination with the optical guiding properties of hollow core fibers to enable a hybrid sensor for electro-magnetic fields. We will report on the status of our work on creating and maintaining suitable ultra-high vacuum conditions for an enclosed cesium vapor within an all-fiber-based device as well as our latest results on 3-photon-excitation schemes inside various types of hollow core fibers.

Q 62.23 Thu 17:00 C/Foyer

Construction of a lithium quantum gas machine — •Andreas Kerkmann, Jan Mika Jacobsen, Niels Rohweder, Benno Rem, Christof Weitenberg, and Klaus Sengstock — Institut für Laserphysik, Hamburg, Germany

We are setting up a new quantum gas machine for the preparation of small degenerate samples of Lithium atoms. In this poster, we present the planned setup and its current status. The laser system has master lasers on the D2 line for the operation of a MOT and on the D1 line for the operation of a grey molasses. The lasers are locked using spectroscopy in lithium heat pipes. The master lasers then seed TAs, which provide the light for a 2D-MOT and a 3D-MOT. The repumping transition frequency is added by modulating the light with an EOM, thus allowing the operation of lambda-enhanced grey molasses. We plan to directly load a crossed optical dipole trap at 1070 nm from the molasses. The laser system is designed to easily switch between the ^{6}Li and ^{7}Li isotopes.

Q 62.24 Thu 17:00 C/Foyer

Optimized Setup for Quantum Logic Spectroscopy of single Molecular Ions — •Jan Christoph Heip[1], Fabian Wolf[1], Florian Gebert[1], Yong Wan[1], and Piet O. Schmidt[1,2] — [1]QUEST Institut, Physikalisch-Technische Bundesanstalt, Braunschweig, Germany — [2]Institut für Quantenoptik, Leibniz Universität Hannover, Germany

Molecular ions have a rich level structure and therefore are useful for applications ranging from precision measurements to quantum information processing. Besides the motional degrees of freedom, they exhibit also vibrational and rotational degrees of freedom, rendering direct laser cooling a challenge. We demonstrate sympathetic motional ground state cooling of a $^{24}MgH^+$ molecular ion through a co-trapped $^{25}Mg^+$ ion. Furthermore, we present first results on the dispersive interaction with an oscillating dipole force coupling internal and external degrees of freedom of the molecular ion. Finally, the design of a new vacuum system will be presented which will allow loading and trapping of other molecular ion species with applications for tests of fundamental physics.

Q 62.25 Thu 17:00 C/Foyer

Non-cryogenic fiber amplifier for optical trapping of neutral mercury — •Holger John and Thomas Walther — Technische Universität Darmstadt, Institut für Angewandte Physik, Schlossgartenstraße 7, 64289 Darmstadt

Laser-cooled mercury constitutes an interesting starting point for various experiments, in particular in light of the existence of bosonic and fermionic isotopes. On the one hand the fermionic isotopes could be used to develop a new time standard based on a optical lattice clock employing the $^1S_0$ - $^3P_0$ transition. Another interesting venue is the formation of ultra cold Hg-dimers employing photo-association and achieving vibrational cooling by employing a special scheme.

The requirements for trapping neutral mercury are given by the cooling transition at 253.7 nm with a linewidth of 1.27 MHz. Our approach is to frequency double a Yb-doped fiber amplified ECDL twice with the fundamental wavelength of 1014.8 nm.

In the recent past fiber amplifiers cooled to cryogenic temperatures have been used due to the high absorption at room temperature. We have developed a non-cryogenic setup which shows a slope-efficiency of more than 35 % and a beam and polariation stability of more than 95 % without any disturbance by the cooling system. We will report on the status of the experiments.

Q 62.26 Thu 17:00 C/Foyer

Double-MOT fluorescence detection on a mesoscopic atom chip — •Ilka Kruse, Jan Mahnke, Andreas Hüper, Wolfgang Ertmer, and Carsten Klempt — Institut für Quantenoptik, Leibniz Universität Hannover

We demonstrate simultaneous fluorescence detection of two mesoscopic atomic ensembles in a MOT configuration using one set of MOT beams. Two magnetic quadrupole fields are generated with a versatile mesoscopic atom chip [1], allowing for the simultaneous operation of two mirror MOTs. The performance of the double-MOT is efficiently optimized by a genetic optimization algorithm [2], yielding a maximum of $9 \cdot 10^9$ atoms in the two MOTs. Fluorescence detection using MOTs is especially well-suited to count the number of atoms with high accuracy. The simultaneous detection of two atom clouds allows for interferometric measurements on the Heisenberg limit. Our approach can be easily scaled to detect more than two components, as desired for sub-shot-noise measurements with spin dynamics in Bose-Einstein condensates [3].

[1] S. Jöllenbeck et al., Phys. Rev. A 83, 043406 (2011)
[2] I. Geisel et al., Appl. Phys. Lett. 102, 214105 (2013)
[3] B. Lücke et al., Science 334, 773 (2011)

Q 62.27 Thu 17:00 C/Foyer

Digital high bandwidth controller for optical traps — •Florian Seidler — Institut für Angewandte Physik, Uni Bonn

Trapped single atoms and atomic ensembles represent a versatile platform for the investigation and application of quantum physics with an extraordinary level of control. One key component to realize coherent manipulation of neutral atoms are versatile control devices. We report on the development of a digital high bandwidth (8 MHz) controller to control optical potentials.

Many parts of control loops used in our research (e.g. AOMs) show nonlinear behaviour that cannot be optimally controlled by inherently linear PID controllers. It requires a great effort to tailor an analog solution to a specific nonlinear control problem. Digital controllers using FPGAs can implement these solutions more easily and rapidly and can be adapted to completely different applications by simply changing the programming. Therefore they might prove superior in many cases.

Q 62.28 Thu 17:00 C/Foyer

Quantum Gases of Light in Variable Potentials — •David Dung, Dario Bashir-Elahi, Tobias Damm, Julian Schmitt, Christian Wahl, Frank Vewinger, Jan Klärs, and Martin Weitz — Institut für Angewandte Physik, Universität Bonn

Bose-Einstein condensation, the macroscopic ground state occupation of bosonic particles at low temperature and high density, has previously been observed for cold atomic gases and solid state quasiparticles. In recent work, our group has realized Bose-Einstein condensation of photons in a dye-filled optical microcavity. In this experiment, a number conserving thermalization process is achieved by multiple absorption and fluorescence processes of dye-molecules. The microcavity creates a confining potential, providing a suitable ground state and leading to a non-vanishing effective photon mass. Formally, the system is equivalent to a two-dimensional gas of trapped, massive bosons.

Here we report on recent work to create multiple BECs of photons in a single microcavity. The BECs are trapped in variable potentials that are induced by locally changing the refractive index inside the microcavity. In the experiment this is realized by focused laser light that heats an absorptive thin film near the mirror surface. A thermo-responsive polymer mixed with the dye solution will then undergo a phase-transition and thereby change the refractive index. Recently, we determined the range of depths and trapping frequencies one can adjust with this technique to create variable potentials for light. Moreover, we show efforts to observe tunneling of photons between lattice sides.

Q 62.29 Thu 17:00 C/Foyer

Dynamical localization in a quantum André-Aubry potential — •Katharina Rojan[1], Hessam Habibian[2,3], Anna Minguzzi[4], and Giovanna Morigi[1] — [1]Theoretische Physik, Universität des Saarlandes, D-66123 Saarbrücken, Germany — [2]Departament de Física, Universitat Autònoma de Barcelona, E-08193 Bellaterra, Spain — [3]Institut de Ciéncies Fotóniques (ICFO), Mediterranean Technology Park, E-08860 Castelldefels (Barcelona), Spain — [4]Laboratoire de Physique et Modélisation des Milieux Condensés, C.N.R.S, B.P. 166, 38042 Grenoble, France

We study the dynamics of a single cold atom tightly confined in an optical lattice, whose dipolar transition strongly couples with a second sinusoidal potential at a different wavelength than the confining lattice. When the second lattice is originated by the coupling with a standing-wave cavity, then its form depends nonlinearly on the atomic wave function. We determine the ground state of the atom by solving self-consistently the corresponding master equation. We identify the conditions under which phenomena occur that are analogous to localization in the André-Aubry model, and discuss the features which are exquisitely due to the quantum nature of the cavity potential.

Q 62.30 Thu 17:00 C/Foyer

Trajectory-based micromotion compensation — Timm F. Gloger, Peter Kaufmann, •Delia Kaufmann, Thomas Collath, M. Tanveer Baig, Michael Johanning, and Christof Wunderlich — Universität Siegen, NT Fakultät, Department Physik, 57068 Siegen, Germany

For experiments with ions confined in a Paul trap, minimization of micromotion is often essential, e.g. in optical ion trapping, combined traps for neutral atoms and ions, or precision measurements. In order to diagnose and compensate micromotion we have implemented a method that allows for finding the position of the rf null reliably and efficiently, in principle, without any variation of dc voltages.

We apply a trap modulation technique and tomographic imaging to extract 3-d ion positions for various rf drive powers and analyze the power dependence of the equilibrium position of the trapped ion. Given sufficient knowledge about the trapping potential, the position of the rf null can be found efficiently without any variation of dc voltages by extrapolating the ion's path to infinite rf power. In the case of significant uncertainties in the trapping potentials or substantial deviations of the potentials from being harmonic, parallel analysis of measurements for different compensation fields quickly yields not only a prediction of the rf null position but also the required compensation voltages. The method is also applied to measure the light pressure of a near resonant laser and it's shift of the ion's equilibrium position.

Q 62.31 Thu 17:00 C/Foyer

Tailoring the anharmonicity of the axial trapping potential an segmented micro-structured ion trap — •M. Tanveer Baig, Timm F. Gloger, Peter Kaufmann, Delia Kaufmann, Thomas Collath, Michael Johanning, and Christof Wunderlich — Faculty of Science and Technology, Department of Physics, University of Siegen, Walter Flex Str. 3, 57072 Siegen, Germany

The anharmonicity of an ion trap, often considered only as a perturbation, might be be decisive when splitting and merging ion strings and can also be an interesting tool to tailor normal modes and the coupling of ions and to create long ion strings. Here we tailor the anharmonicity of the axial trapping potential in a segmented micro-structured ion trap and quantify it by analyzing the axial center of mass (COM) and breathing mode of strings of up to two ions. Mode frequencies were determined by applying a small, near resonant tickling voltage to dc segment electrodes nearby and observing the drop in ion fluorescence, when the ions were resonantly heated.

The ratio of the breathing and COM mode frequency is expected to be $\nu_{\mathrm{breathe}}/\nu_{\mathrm{COM}} = \sqrt{3}$ for a perfect harmonic trap, due to the curvature of the Coulomb potential at the equilibrium separation of the ions. Interpolating between two different potentials with anharmonicities of different size and opposite sign, we are able to deviate from this value and we can show that we are able to tailor the anharmonicity while maintaining a constant curvature and thus COM mode within a range given by the voltage limitations of our voltage source [1].

[1] M. T. Baig et al., Rev. Sci. Instrum. 84, 124701 (2013)

Q 62.32 Thu 17:00 C/Foyer

A versatile transport apparatus for the production of ground-state RbYb — •Simone Kipp, Tobias Franzen, Alina Hoppe, Christian Keller, Lukas Mehring, Kapilan Paramasivam, Bastian Pollklesener, Markus Rosendahl, Bastian Schepers, Ralf Stephan, 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 measurement 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.

Separate production chambers allow the parallel production of Yb and Rb samples. Optical tweezers transport both species to a separate science chamber. This chamber provides excellent optical access and room for additional components in- and outside of the vacuum.

[1] F. Münchow et al., PCCP 13(42), 18734 (2011).
[2] M. Borkowski et al., PRA 88, 052708 (2013)

Q 62.33 Thu 17:00 C/Foyer

towards resolved sideband spectroscopy of barium ion in a hybrid atom-ion experiment — •Amir Mahdian, Joschka Wolf, Artjom Krükow, Amir Mohammadi, and Johannes Hecker denschlag — Institut für Quantenmaterie, Universität Ulm, Deutschland

In our hybrid atom-ion experiment we investigate the interaction of cold Ba^+ ions with ultracold Rb atoms. A reliable way of measuring the ion temperature would enhance our understanding of the dynamics of atom-ion interactions. A resolved sideband system is therefore being implemented into our setup alongside providing the possibility to cool down the ion beyond the Doppler limit. The $6S_{1/2} \rightarrow 5D_{5/2}$ transition is chosen for our sideband system. Therefore, a narrow band laser is provided to derive the shelving transition at 1762 nm. To achieve a linewidth much smaller than the typical trapping frequencies of our Paul trap(40 kHz) and long term frequency drifts in the sub kHz regime, we set up a high-Q optical cavity. In order to stabilize the laser to this cavity we will use a broadband electro-optical modulator operated in a two-tone configuration [1]. In addition to this shelving laser, we need a second laser resonant to the $5D_{5/2} \rightarrow 6P_{3/2}$ transition in order to deshelve the ion. A sum frequency mixing technique has been employed to generate 614 nm light using two high-power lasers at 1064 nm and 1450 nm. In this poster we show our progress and the capabilities of such a system.

[1] J.I. Thorpe, K.Numata, J.Livas, Opt. Expr. **16** 15980(2008)

Q 62.34 Thu 17:00 C/Foyer

Coherent interactions in a one-dimensional ultracold medium of extreme optical depth — •Frank Blatt, Thomas Halfmann, and Thorsten Peters — Institut für Angewandte Physik, Technische Universität Darmstadt, Hochschulstraße 6, 64289 Darmstadt, Germany

Engineering strong light-matter interactions at the single photon level is a key requirement for quantum information processing, or the generation of strongly correlated quantum light-matter systems. Typically, these light-matter interactions are maximized by tightly confining both matter and light. A promising method towards tight confinement is based on transferring laser-cooled atoms from a magneto-optical trap into a hollow-core photonic crystal fiber (HCPCF) and guiding the atoms in the device by a red-detuned optical dipole trap.

We here report on the preparation of such one-dimensional ultracold medium inside a HCPCF, reaching an effective optical depth (OD) of 1000 on an open transition. This OD corresponds to around 2.5*10^5 atoms loaded into the core with a loading efficiency of 2.5%. We present measurements of the number of atoms inside the fiber and of the absorption spectrum, which allows us to determine the OD. Furthermore, we demonstrate the successful implementation of electromagnetically induced transparency (EIT) which renders the highly opaque medium transparent. This combination of EIT and a tightly confined ultracold medium of extreme OD paves the way towards quantum nonlinear optics with Kerr-type nonlinearities.

Q 62.35 Thu 17:00 C/Foyer

Photonic crystal fibre technology based ion traps — •Frieder Lindenfelser[1], Ben Keitch[1], Patrick Uebel[2], Bmitry Bykov[2], Markus Schmidt[3], Philip St.J. Russell[2], and Joathan Home[1] — [1]ETH, Zürich, Schweiz — [2]MPL, Erlangen, Deutschland — [3]IPHT, Jena, Deutschland

We demonstrate a surface-electrode ion trap fabricated using techniques transferred from the manufacture of photonic crystal fibres (PCFs). A pre-step to a drawn out PCF is a cane that has the same regular hole pattern at a larger (100 micron) size. Filling the holes with gold wires and using them as electrodes provides a relatively straightforward route for realizing traps with electrode structure on the 100 micron scale with high optical access. This makes it useful for interaction with strongly focused laser beams and cavity integration. The fabrication method should allow building traps of similar geometry at sizes on the 10 - 100 microns range that might allow trapping at the tip of an optically guiding PCF, and provide a route towards small two dimensional arrays of ion traps.

Q 62.36 Thu 17:00 C/Foyer

Effect of photon absorption in optical phase gratings for matter waves — •Kai Walter, Stefan Nimmrichter, and Klaus Hornberger — Fakultät für Physik, Universität Duisburg-Essen, Deutschland

Optical elements, such as a standing wave laser grating, play an important role in matter wave interferometry with large molecules. For their theoretical description we have to distinguish several types of interactions: the coherent laser-dipole interaction due to the molecular polarizability, the incoherent absorption of laser photons, and radiative decay. Moreover, changes of the internal molecular state due to the electronic excitation and relaxation can also be relevant. The interplay of these effects can be described by a quantum master equation for the center-of-mass and the internal state. We will also discuss how this description is related to the Rabi model for the laser-atom interaction.

The results are discussed by means of concrete experimental setups with a standing wave laser grating: near field interferometry with large molecules [1] and the optical mask for laser-cooled atoms [2].

[1] M. Arndt et al., Nature Physics 3, 711 - 715 (2007)
[2] A. Turlapov et al., Phys. Rev. A 68, 023408 (2003)

Q 62.37 Thu 17:00 C/Foyer

Gravimetry with ultra-cold atoms based on atom-chip sources — •Matthias Gersemann[1], Jonas Matthias[1], Maral Sahelgozin[1], Holger Ahlers[1], Sven Abend[1], Martina Gebbe[2], Hauke Müntinga[2], Waldemar Herr[1], Wolfgang Ertmer[1], and Ernst Maria Rasel[1] — [1]Institut für Quantenoptik, LU Hannover — [2]ZARM, Universität Bremen

Today atom-chip based setups provide the reliable generation of ultracold atomic ensembles and appear therefore as ideal sources for atom interferometry. We present a setup based on such a source in combination with Bragg-type beam splitters to coherently manipulate not only BECs of ^{87}Rb atoms but furthermore magnetically lensed ensembles. The main advantage of the extremely low momentum spread of a collimated BEC lies in the reduction of systematic errors arising from wave front inhomogeneities of the beam splitting light fields, which is a limitation to the precision of the current generation atomic gravimeters. On this poster, we discuss the application of atom-chip technology to atomic gravimetry under consideration of effective atomic flux, atomic sample temperature equivalent, and compactness of the experimental setup. We also study the application of new interferometer topologies accessible with atomic samples of low momentum spread in order to increase the sensitivity and find out more about limitations to ultracold gravimeters.

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 DLR 50WM1131.

Q 62.38 Thu 17:00 C/Foyer

Many-body scattering of atoms through mesoscopic cavities: Universal effects of indistinguishability and interactions — •Josef Michl[1], Markus Biberger[1], Jack Kuipers[2], Juan Diego Urbina[1], and Klaus Richter[1] — [1]Institut für Theoretische Physik, Universität Regensburg, 93053 Regensburg, Germany — [2]Computational Biology Group, ETH Zürich, 8092 Zürich, Switzerland

We report progress in constructing a theory for scattering of identical particles through open mesoscopic cavities suitable for studying the interplay between three physical effects: universality of single-particle transport in the presence of chaos, many-body correlations due to quantum indistinguishability similar to the Hong-Ou-Mandel effect in quantum optics, and the presence of interparticle interactions. Already in the case of non-interacting bosons being transmitted through a chaotic cavity, a mesoscopic version of the Hong-Ou-Mandel profile was obtained because of non-trivial combinations of single-particle scattering matrices due to the symmetrization principle [1]. Going beyond non-interacting systems, we construct a universal Hamiltonian for open chaotic cavities representing interactions in the basis of single-particle scattering states. For bosonic systems, this Hamiltonian is ready to be used in the non-perturbative framework of a functional truncated Wigner approximation [2]. We apply this idea to investigate how the interplay between interaction effects and correlations due to indistinguishability affects observables like the current.

[1] J. D. Urbina, J. Kuipers, Q. Hummel, K. Richter, arXiv:1409.1558
[2] e.g. B. Opanchuk, P. D. Drummond, J.Math.Phys. 54, 042107(2013)

Q 62.39 Thu 17:00 C/Foyer

A bottom-up approach to Poisson spot experiments with neutral matter-waves — •Thomas Reisinger, Arne Fischer, Christian Reitz, Herbert Gleiter, and Horst Hahn — Karlsruhe Institute of Technology, Eggenstein-Leopoldshafen, Germany

Poisson's spot refers to the positive on-axis interference of waves in the circular shadow of a disc or sphere. Its intensity strongly depends on the surface corrugation of the diffraction object, especially in experiments characterized by a Fresnel number greater than one. Due to the small de-Broglie wavelength commonly involved (of the order of a few picometer), neutral matter-wave diffraction experiments often belong to this category.

For this reason we have developed a technique to perform Poisson spot experiments using spherical sub-micron silicon-dioxide particles as diffraction objects. They were prepared following a bottom-up approach, namely the Stoeber process, which results in particularly low surface corrugation of the particles - potentially lower than gratings prepared with common top-down lithography techniques. We evaluate the prospect of performing Poisson spot experiments with more massive and complex matter-waves using this approach. Furthermore, since the intensity of Poisson's spot is a sensitive probe for forces between matter-wave and the diffraction object, we expect the experiments to yield data that can be used to verify models describing the Casimir-Polder potential.

Q 62.40 Thu 17:00 C/Foyer

Towards a unified description of time independent matter-wave interferometers — •Alexander Friedrich, Enno Giese, and Wolfgang P. Schleich — Institut für Quantenphysik and Center for Integrated Quantum Science and Technology (IQ^{ST}), Universität Ulm, Albert-Einstein-Allee 11, D-89081 Ulm, Germany

Single-crystal neutron interferometers, as used in the landmark COW-experiment[1], differ significantly in their theoretical description from the more recent class of light pulse atom interferometers like the Kasevich-Chu interferometer. Both interferometers permit measurements of the gravitationally induced phase-shift in matter-waves. The latter can be described solely in terms of a theory based on the time dependent Schrödinger equation[3] while the first is heavily reliant on solving the time independent Schrödinger equation in position-space by employing dynamical diffraction inside the crystal and using path integrals in the gravitational field. This dependence on the combination of two fundamentally different approaches to quantum mechanics is non-satisfying from a theoretical point of view. Nevertheless it is possible to show that the classical beam trajectories in a COW- and Mach-Zehnder type atom interferometer are equivalent to first order.[2,4] In our work we therefore investigate a unified approach to the description of time independent matter-wave interferometers.

[1] R. Colella et al., Phys. Rev. Lett. 3, 1472-1474 (1975)
[2] D. Greenberger et al., Phys. Rev. A. 86, 063622 (2012)
[3] W. P. Schleich et al., Phys. Rev. Lett. 110, 010401 (2013)
[4] H. Lemmel, ArXiv e-prints id:1406.1328 (2014)

Q 62.41 Thu 17:00 C/Foyer

QUANTUS 2 - a matter wave interferometer in extended free fall — •Alexander Grote[1], Klaus Sengstock[1], and the QUANTUS Team[1,2,3,4,5,6,7,8,9] — [1]Institut für Laserphysik, Universität Hamburg — [2]Institut für Quantenoptik, Universität Hannover — [3]Institut für Physik, Humbolt Universität zu Berlin — [4]ZARM, Universität Bremen — [5]Institut für Physik, Johannes Gutenberg-Universität — [6]Ferdinand-Braun-Institut, Berlin — [7]Institut für Quantenphysik, Universität Ulm — [8]Institut für angewandte Physik, TU Darmstadt — [9]MPQ, Garching

Inertial sensors based on cold atoms are an outstanding tool for fundamental physics research under microgravity such as testing the Einstein equivalence principle. Here we present the first results of our apparatus after drops and catapult shots in the Bremen drop tower. During a microgravity time of 9s the apparatus is capable of subsequently producing and performing experiments with up to four ^{87}Rb BECs. During the first drop and catapult campaigns we found that the position and dynamics of the atoms closely follow the predictions made by an extensive simulation of our magnetic chip. By implementing magnetic lensing we will be able to demonstrate atom interferometry with unprecedented interrogation times. For future campaigns the setup will be modified to produce mixtures of both Rubidium and Potassium for dual species atom interferometry.

The QUANTUS project is supported by the German Space Agency DLR with funds provided by the Federal Ministry of Economic Affairs and Energy (BMWi) under grant number DLR 50WM1131-1137.

Q 62.42 Thu 17:00 C/Foyer

Representation-free description of light-pulse atom interferometry including non-inertial effects — •Stephan Kleinert, Endre Kajari, Albert Roura, Wolfgang P. Schleich, and the QUANTUS Team — Institut für Quantenphysik and Center for Integrated Quantum Science and Technology (IQ^{ST}), Universität Ulm

The coherent manipulation of atoms by laser pulses enables the use of atom interferometers for gravimetry and inertial sensing, accurate measurements of fundamental constants and tests of fundamental properties.

Here we provide a versatile representation-free description of atom interferometry including the effects of quadratic external potentials (e. g. due to gravity gradients) as well as arbitrary time-dependent accelerations and rotations [1]. In particular, our approach can easily model interferometers embedded in non-inertial reference frames necessary for microgravity experiments in drop-tower facilities, sounding rockets or dedicated satellite missions.

The QUANTUS project is supported by the German Space Agency (DLR) with funds provided by the Federal Ministry of Economics and Technology (BMWi) under grant number 50WM1136.

[1] S. Kleinert et al., Representation-free description of light-pulse atom interferometry including non-inertial effects, Phys. Rep. (to be published).

Q 62.43 Thu 17:00 C/Foyer

Compact and stable laser systems for atom interferometry with ^{41}K in microgravity — •Aline Dinkelaker[1], Max Schiemangk[1,2], Kai Lampmann[3], and Achim Peters[1,2] for the QUANTUS-Collaboration — [1]Humboldt-Universität zu Berlin — [2]Ferdinand-Braun-Institut, Leibniz-Institut für Höchstfrequenztechnik, Berlin — [3]Johannes Gutenberg-Universität Mainz

In the recent past, atom interferometry emerged as a promising tool for precision metrology and tests of fundamental physics. We aim to utilise this tool for tests of Einstein's equivalence principle in microgravity using atoms as test masses. Experiments in microgravity with ^{87}Rb atoms have been successfully performed in drop tower experiments as part of the QUANTUS project. The next generation drop tower experiment is designed for dual species atom interferometry with ^{87}Rb and ^{41}K, for which an additional laser system is necessary. As for the existing Rubidium setup it must be compact and robust in order to fulfil the tight spatial constraints and to withstand the strong acceleration in the drop tower. Additionally, the small hyperfine structure of ^{41}K complicates the optical cooling scheme. These challenges are met by including custom made hybrid integrated master-oscillator power amplifiers in combination with a careful design of the optical components and the overall layout. This will provide a further step towards tests of the equivalence principle using atom interferometry.

This project is supported by the German Space Agency DLR with funds provided by the Federal Ministry for Economic Affairs and Energy under grant number DLR 50WM1131-1137.

Q 62.44 Thu 17:00 C/Foyer

Laser systems for atom interferometry aboard sounding rockets — •Vladimir Schkolnik[1], Markus Krutzik[1], Achim Peters[1,2], The MAIUS Team[1,2,3,4,5], The FOKUS Team[1,2,3,4], and The KALEXUS Team[1,2,4,5] — [1]Institut für Physik, Humboldt-Universität zu Berlin — [2]Ferdinand-Braun-Institut, Leibniz-Institut für Höchstfrequenztechnik, Berlin — [3]ILP, Universität Hamburg — [4]Institut für Physik, JGU Mainz — [5]IQO, Leibniz Universität Hannover

Laser systems with precise and accurate frequencies is the key element in high precision experiments such as atom interferometers and atomic clocks. Future space missions including quantum based tests of the equivalence principle or the detection of gravitational waves will need robust and compact lasers with high mechanical and frequency stability.

We present a new generation of compact laser systems optimized for precision measurement applications with ultra-cold atoms aboard sounding rockets. Design, assembly and qualification of a system capable of atom interferometric experiments with degenerate 87Rb in context of the MAIUS mission will be discussed.

Laser spectroscopy payloads for two other sounding rocket experiments are also presented. FOKUS, which will operate together with a rocket-borne frequency comb on the TEXUS 51 mission and KALEXUS, a laser system containing two narrow linewidth extended cavity diode lasers (ECDLs) for potassium spectroscopy. All laser systems are to be launched within the next 12 months.

Q 62.45 Thu 17:00 C/Foyer

General Relativistic Corrections for Bose-Einstein Condensates in Local Frames — •Oliver Gabel and Reinhold Walser — Institut für Angewandte Physik, Technische Universität Darmstadt, Hochschulstr. 4a, 64289 Darmstadt

Measuring general relativistic effects in the gravitational field of the Earth is a main goal of current research in atom interferometry. In this context, the QUANTUS collaboration is aiming at the verification of the Einstein equivalence principle for quantum matter, having demonstrated Bose-Einstein condensates (BECs) and interferometry in free fall [1,2].

Thus, it is relevant to develop a relativistic description of BECs and to systematically characterise the arising corrections to Newtonian physics. We employ an extension of local inertial frames in terms of Fermi normal coordinates and a mean-field description of free falling BECs based on the non-linear covariant Klein-Gordon equation to study the frame-dependent corrections to equations of motion [3] and the interferometric phase shift in Schwarzschild space-time.

[1] T. van Zoest et. al., *Bose-Einstein Condensation in Microgravity*, Science, **328**, 1540 (2010).
[2] H. Müntinga et. al., *Interferometry with Bose-Einstein Condensates in Microgravity*, Phys. Rev. Lett. **110**, 093602 (2013).

[3] O. Gabel and R. Walser, *Tidal Corrections for Free Falling Bose Einstein Condensates in General Relativity*, submitted (2015).

Q 62.46 Thu 17:00 C/Foyer

Experimental investigation of momentum space signatures of Anderson localization — •Valentin V. Volchkov[1], Jérémie Richard[1], Vincent Denechaud[1], Guillaume Berthet[1], Kilian Müller[1], Philippe Bouyer[2], Alain Aspect[1], and Vincent Josse[1] — [1]Laboratoire Charles Fabry UMR 8501, Institut d'Optique, CNRS, Univ Paris Sud 11, 2 Avenue Augustin Fresnel, 91127 Palaiseau cedex, France — [2]LP2N UMR 5298, Univ Bordeaux 1, Institut d'Optique and CNRS, 351 cours de la Libération, 33405 Talence, France.

Phase coherence has dramatic effects on the transport properties of waves in random media, leading eventually to a complete halt of the wave, i.e. Anderson localization. Recently, new ideas have emerged, as for instance the search for original signatures of Anderson localization in momentum space. We present our investigations along that line using ultracold atoms in a laser speckle potential. On the one hand, the observed Coherent Backscattering with ultracold atoms constitutes the first direct signature of phase coherence in ultracold disordered gases [1]. For strong disorder, on the other hand, a "Coherent Forward Scattering" (CFS) has been theoretically predicted [2] and could be used to give unambiguous signature of the onset of Anderson localization. We implement the proposal by Lee et al [3] to observe CFS in 1D by launching an atomic wavepacket into a highly anisotropic disorder potential. Preliminary results are discussed.

[1]: F. Jendrzejewski et al., *PRL* **109**, 195302 (2012). [2]: T. Karpiuk et al., *PRL* **109**, 190601 (2012). [3]: K. L. Lee et al., *PRA* **90**, 043605 (2014).

Q 62.47 Thu 17:00 C/Foyer

Realizing a sub-kelvin membrane-in-the-middle fiber cavity — •Hai Zhong, Philipp Christoph, Andreas Bick, Christina Staarmann, Jannes Heinze, Ortwin Hellmig, Christoph Becker, Alexander Schwarz, Klaus Sengstock, and Roland Wiesendanger — Zentrum für Optische Quantentechnologien, Universität Hamburg, Deutschland

A fiber cavity based membrane-in-the-middle (MiM) setup has great potential to cool down a massive mechanical oscillator, e.g., a Si_3N_4 membrane to its quantum mechanical ground state via hybrid optomechanical cooling schemes. Moreover, its miniaturized size is compatible with the limited space available in cryogenic set-ups. Our dilution fridge will be used to precool the membrane to sub-kelvin temperatures before starting optomechanical cooling. The MiM set-up consists of two reflective micro-mirrors formed by the end of two opposing optical fibers. Each fiber can be adjusted using home-built 5-axis goniometer stages, powered by piezo-electric motors [1]. The membrane can be inserted *in situ* by an exchangeable shuttle with the possibility of being excited via a piezoelectric element. Here we report on the performance of the MiM set-up in the cryogenic environment, e.g., cooling power, base temperature and fiber alignment. Our next step is to couple the sub-kelvin cold membrane with ^{87}Rb ultracold atoms in an optical lattice. This work is supported by the "GRK 1355".

[1] H. Zhong, et al., Rev. Sci. Instrum. 85, 045006 (2014).

Q 62.48 Thu 17:00 C/Foyer

Asymmetric fiber cavities for quantum opto-mechanics with SiN-membranes — •Philipp Christoph, Andreas Bick, Christina Staarmann, Hai Zhong, Alexander Schwarz, Roland Wiesendanger, Ortwin Hellmig, Jannes Heinze, Christoph Becker, and Klaus Sengstock — Zentrum für Optische Quantentechnologien, Universität Hamburg, Deutschland

We are currently setting up a quantum hybrid experiment, which aims at coupling a Bose-Einstein condensate to a cryogenically pre-cooled SiN membrane via long-range light interaction. A fiber cavity is used to enhance the coupling between light and membrane by a factor of the finesse. Asymmetric coating of the cavity mirrors enables finite on-resonance reflection required to establish a mutual resonant coupling between the BEC and the membrane motion. Our results reveal that the on-resonance reflectivity is extremely sensitive to the mode match between fiber- and cavity mode. Best mode match is achieved for plano-concave cavities. Using standard single mode fibers with mode field diameter of $5.2\mu m$, we derive an optimal mode match for a radius of curvature close to $50\mu m$ and cavity length of $L \approx 25\mu m$. In this way we achieve values for the on-resonance power reflection ideally suited for our envisaged quantum hybrid system.

Q 62.49 Thu 17:00 C/Foyer

Transverse Mode Coupling and Diffraction Loss in Fibre-Based Microcavities — •Julia Benedikter[1,2], Thomas Hümmer[1,2], Matthias Mader[1,2], Theodor W. Hänsch[1,2], and David Hunger[1,2] — [1]Ludwig-Maximilians-Universität München, Schellingstr. 4, 80799 München — [2]Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Str. 1, 85748 Garching

Fibre-based Fabry-Pérot resonators provide very small mode volumes and high finesse in a tuneable and accessible geometry [1, 2]. This makes them attractive for various applications ranging from cold atom and ion experiments to cavity optomechanics and cavity-enhanced single photon sources. In contrast to macroscopic cavities, the mirrors are not spherical, but rather have a nearly Gaussian profile originating from the laser machining process used to shape the fibre surface. We find that non-spherical mirror shape and finite mirror size lead to loss, mode deformation, and frequency shifting at particular mirror separations. For long cavities, diffraction loss limits the useful mirror separation to values below the expected stability range. Using scanning cavity microscopy, we observe spatially localised coupling resonances, owing to a variation of the mirror properties. We attribute these findings to resonant coupling between different transverse modes of the cavity and show that a model based on resonant state expansion [3] taking into account the measured mirror profile can reproduce the measurements.

[1] Hunger et al., NJP 12, 065038 (2010)
[2] Hunger et al., AIP Advances 2, 012119 (2012)
[3] Kleckner et al., PRA 81, 043814 (2010)

Q 62.50 Thu 17:00 C/Foyer

Ultra-small mode volume cavities for the enhancement of nitrogen-vacancy center fluorescence — •Hanno Kaupp[1,2], Benedikt Schlederer[1,2], Helmut Fedder[3], Huan-Cheng Chang[4], Theodor W. Hänsch[1,2], and David Hunger[1,2] — [1]Ludwig-Maximilians-Universität, 80799 München, Germany — [2]Max-Planck-Institut für Quantenoptik, 85748 Garching, Germany — [3]Universität Stuttgart, 70569 Stuttgart , Germany — [4]Academia Sinica, Taipei 106, Taiwan

We apply tunable optical fiber microcavities to enhance the emission rate and to increase the coupling efficiency of Nitrogen-vacancy (NV) centers in diamond. Using diamond nanocrystals large enough to provide nanoscale field confinement by themselves ultimately small mode volumes can be realized. Embedding the crystals in between two silver mirrors a Fabry-Perot cavity mode can be defined with mode volumes down to $0.1\,(\lambda/n)^3$. The resulting large Purcell enhancement ($C \sim 5$) and efficient outcoupling of the photons provide a way to build efficient solid state single photon sources as well as efficient spin-photon interfaces at ambient conditions. We show emission lifetime changes by a factor of two for NV center ensembles, as well as an increase of collected photons by roughly an order of magnitude for single emitters.

Q 62.51 Thu 17:00 C/Foyer

Cavity-enhanced Scanning Raman-Spectroscopy of single Carbon Nanotubes — •Thomas Hümmer[1,2], Matthias S. Hofmann[1], Jonathan Noe[1], Alexander Högele[1], Theodor W. Hänsch[1,2], and David Hunger[1,2] — [1]Ludwig-Maximilians-Universität München, Deutschland — [2]Max-Planck Institut für Quantenoptik, Garching, Deutschland

We use fully tunable fiber-based optical microcavities [1] with small mode volumes and high quality factors to study carbon nanotubes. We detect Raman scattering of individual CNTs strongly enhanced by the Purcell effect. Since the spectral emission is increased on the order of the cavity Finesse, which can be as large as 10^5, this enables us to measure Raman spectra with high sensitivity and spectral resolution. Harnessing the full tunability and open access of these micro-cavities allows us to perform scanning measurements, addressing a variety of nanotubes individually at different locations and wavelengths. We compare the cavity enhanced detection to diffraction limited confocal measurements carried out on exactly the same CNTs. This yields a more than an order of magnitude enhanced collection efficiency, in agreement with theoretical predictions. Straightforward improvements are expected to lead to significantly larger signals.
[1] Hunger, Reichel et al., NJP 12, 065038 (2010)

Q 62.52 Thu 17:00 C/Foyer

A Scanning Cavity Microscope — •Matthias Mader[1,2], Jakob Reichel[3], Theodor W. Hänsch[1,2], and David Hunger[1,2] — [1]Ludwig-Maximilians-Universität München, Fakultät für Physik, Schellingstraße 4, 80799 München — [2]Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Straße 1, 85748 Garching — [3]Laboratoire Kastler Brossel, ENS/UPMC-Paris 6/CNRS, 24 rue Lhomond, F-75005 Paris

We present a versatile tool for ultra-sensitive and spatially resolved optical characterization of single nanoparticles.

Using signal enhancement in a scanning optical microcavity made of a micromachined optical fiber and a plane mirror [1] together with higher order cavity modes, we measure the polarization dependent extinction and polarizability of a single nanoparticle. Harnessing multiple interactions of probe light with a sample within the optical resonator, we achieve a 1700-fold signal enhancement compared to diffraction-limited microscopy [2]. We demonstrate first quantitative simultaneous measurements of the extinction cross section and polarizability of a single nanoparticle.

These measurements demonstrate the potential of our technique for very sensitive imaging of dispersive nanoparticles like viruses or biomolecules.

[1] D. Hunger, T. Steinmetz, Y. Colombe, C. Deutsch, T. W. Hänsch and J. Reichel, New J. Phys. 12, pp. 065038(2010) [2] M. Mader, J. Reichel, T. W. Hänsch and D. Hunger, arXiv preprint arXiv:1411.7180 (2014)

Q 62.53 Thu 17:00 C/Foyer

Large Purcell enhancement of NV-Center fluorescence in an optical nanocavity — •Pradyumna Paranjape[1], Andreas Weissl[1,2], Hanno Kaupp[1,2], Huan-Cheng Chang[3], Helmut Fedder[4], Theodor Hänsch[1,2], and David Hunger[1,2] — [1]Ludwig-Maximilians-Universität, München, Germany — [2]Max-Planck-Institut für Quantenoptik, Garching, Germany — [3]Institute of Atomic and Molecular Sciences, Academia Sinica, Taipei 106, Taiwan — [4]Universität Stuttgart, 70569 Stuttgart , Germany

Nitrogen-Vacancy centers (NV-centers) in diamond provide bright and stable single-photon emission without photo bleaching in cryogenic as well as ambient environments.

To achieve directional emission, good quantum efficiency and significant Purcell enhancement, we investigate a design where NV-centers in nanodiamonds are coupled to a nanoscale gap between two silver mirrors. In this way, a cavity mode with a mode volume below 0.1(λ/n)3 can be achieved, and large Purcell enhancement (C » 10) is expected. We report on the current status of the experiment.

Q 62.54 Thu 17:00 C/Foyer

Rare-earth-ion doped nanocrystals coupled to a fiber-based microcavity — •Tolga Bagci[1,2], Thomas Hümmer[1,2], Hanno Kaupp[1,2], Andreas Weissl[1,2], Alban Ferrier[3], Philippe Goldner[3], Theodor W. Hänsch[1,2], and David Hunger[1,2] — [1]Ludwig-Maximilians-Universität, München, Germany — [2]Max-Planck-Institut für Quantenoptik, Garching, Germany — [3]Chimie ParisTech, Laboratoire de Chimie de la Matière Condensée de Paris, CNRS-UMR 7574, UPMC Univ Paris 06, Paris, France

Rare-earth-ions doped into solids provide a promising system for quantum optics/information applications due to their narrow linewidths and long-lived quantum coherences. However, their emission rates are typically ultra-low. We present a fiber-based microcavity setup where the emission rate of an Europium-doped nanocrystal (Eu3+:Y2O3) can be enhanced by the Purcell effect, offering the potential for an efficient optical link to single emitters or small ensembles. As a first step, we perform room-temperature confocal microscopy of individual nanocrystals without cavity and assess their fluorescence spectra and emission lifetimes. We furthermore report on our current efforts towards observing Purcell-enhanced emission from ions coupled to a fiber-based microcavity.

Q 62.55 Thu 17:00 C/Foyer

Creation of fluorescent Cerium-Dopants in YAG by Ion Implantation — •Thomas Kornher[1], Nadezhda Kukharchyk[2], Kangwei Xia[1], Roman Kolesov[1], Andreas D. Wieck[2], and Jörg Wrachtrup[1] — [1]3. Physikalisches Institut, Universität Stuttgart, Germany — [2]Lehrstuhl für Angewandte Festkörperphysik, Ruhr-Universität Bochum, Germany

Rare-earth dopants in crystals exhibit long optical coherence times, which makes them promising candidates not only as quantum storage devices for photons. Due to demonstrated detection on a single ion level and optical accessibility of their spin degrees of freedom, such systems are also investigated for their potential as quantum computation platform. Doping of optical crystals by means of ion implantation gives rise to preparation of rare-earth ions in selected locations. Studying their fluorescence yield in optical crystals is a step towards a more controlled fabrication of mentioned quantum devices.
The high quantum yield of Ce^{3+} emission and successful implantation in YAG acts as motivation to further analyze the stabilization of implanted cerium ions in the favored valence state. During implantation and the subsequent annealing process, trivalent cerium ions tend to lose an electron and form a dark tetravalent state. Therefore, investigation of different annealing atmospheres and variation of implantation parameters becomes the focus of attention. Measured fluorescence yield acts as an indicator for the successful activation of implanted cerium ions by annealing in an inert gas atmosphere or alternatively in a reducing one.

Q 62.56 Thu 17:00 C/Foyer

Photonic structures for manipulation of rare-earth ions in thin films — •Bruno Villa[1], Roman Kolesov[1], Kangwei Xia[1], Rolf Reuter[1], Gunther Richter[2], Andrej Denisenko[1], Seyed Ali Momenzadeh[1], and Jörg Wrachtrup[1] — [1]3. Physikalisches Institut, Universität Stuttgart, Germany — [2]Max Planck Institut for Intelligent Systems, Germany

Single rare-earth ions in YAG are attractive candidates for quantum information processing due to inherent properties, foremost of which is the shielding of the optically active 4f electrons by higher orbitals. Previous work in this group has demonstrated detection and addressing of single Ce^{3+} ions in YAG crystals, albeit with low detection efficiency related to the radiative lifetime.

In an effort to enhance the zero phonon line emission and demonstrate cavity quantum electrodynamics on this system, amorphous TiO_2 whispering gallery mode resonators were fabricated on the crystals. Film quality is of utmost importance for figures of merit such as the propagation losses and quality factors of the resonators. Hence, different deposition and patterning methods were tried out. The simulation, fabrication and characterization of these devices is presented.

Q 62.57 Thu 17:00 C/Foyer

Single rare earth ions as a new platform for quantum optics — •Emanuel Eichhammer, Tobias Utikal, Stephan Götzinger, and Vahid Sandoghdar — Max Planck Institute for the Science of Light and Friedrich-Alexander-Universität Erlangen-Nürnberg (FAU), D-91058 Erlangen, Germany

Embedding single quantum emitters in the solid state promises improved accessibility and scalability for many emerging quantum technologies such as quantum memories and networks. Pr^{3+} ions doped in a Y_2SiO_5 crystal have already been used in many interesting ensemble experiments. The spectrally narrow features, the availability of a hyperfine-split ground state and exceptionally long coherence times make this system an ideal platform for quantum information processing. Here we show the successful selection of a single Praseodymium ion from an inhomogeneously broadened ensemble, via two different transitions at 488 nm and 606 nm [1,2]. We present measurements of the second order auto-correlation function $g^{(2)}$, studies of the hyperfine transitions and resonance linewidths, fluorescence lifetime measurements and emission spectra of a single ion. We discuss future plans for the enhancement of the fluorescence signal by coupling single ions to microcavities.

[1] T. Utikal, E. Eichhammer, L. Petersen, A. Renn, S. Götzinger & V. Sandoghdar, *Nat. Commun.* **5**, 3627 (2014). [2] E. Eichhammer, T. Utikal, S. Götzinger & V. Sandoghdar, *in preparation.*

Q 62.58 Thu 17:00 C/Foyer

Generation of squeezed light and quantum correlations from few emitters in a nanostructure — •Harald R. Haakh and Diego Martin-Cano — Max Planck Institute for the Science of Light, Erlangen, Germany.

Squeezed states of light, together with entangled qbit states, provide the most striking examples of quantumness. Despite their high technological relevance, they remain hard to address in resonance fluorescence of individual quantum emitters, which form one of the most fundamental systems in quantum optics [1]. Instead, squeezed light has been commonly generated in large systems such as nonlinear crystals, atomic vapors and microcavities [2,3]. We investigate the generation of squeezed light by one or two quantum emitters coupled to a nanostructure and show how nanoarchitectures strongly modify the creation of squeezed light in resonance fluorescence. This allows for brighter sources with a larger bandwidth and overcoming phononic dephasing

[4], which could lend themselves to the integration in nanophotonic devices. We assess prospects of enhancing the nonlinearity by using a pair of emitters. The results elucidate the connection between squeezed light emission and quantum correlations.

References
[1] Walls and Zoller, Phys. Rev. Lett. **47**, 709 (1981).
[2] Ourjoumtsev et al., Nature **474**, 626 (2011).
[3] Grünwald and Vogel, Phys. Rev. Lett. **109**, 013601 (2012)
[4] Martín Cano, Haakh, Murr and Agio, Phys. Rev. Lett. (2014).

Q 62.59 Thu 17:00 C/Foyer

Modification of the radiative properties of a single emitter by a gold nanocone — •Korenobu Matsuzaki[1], Simon Vassant[1], Björn Hoffmann[1], Silke Christiansen[1,2], Stephan Götzinger[3,1], and Vahid Sandoghdar[1,3] — [1]Max Planck Institute for the Science of Light, Erlangen, Germany — [2]Helmholtz Centre for Materials and Energy, Berlin, Germany — [3]Friedrich Alexander University of Erlangen-Nürnberg, Erlangen, Germany

Plasmonic antennas can dramatically modify the radiative properties of quantum emitters. Recently, we have studied gold nanocones as particularly efficient antenna structures [1]. In the present experimental study, we systematically investigated the optical properties of gold nanocones fabricated by focused ion beam milling. Then, we coupled a single colloidal quantum dot attached to a glass fiber tip, which could be placed in the near field of the nanocone with nanometer accuracy. We present our results concerning fluorescence lifetime reduction larger than 300 times and a strong emission redirection by the nanocones [2]. Furthermore, we investigate the effect of the plasmonic antenna on the basic photophysics of the quantum dot.

[1] X.-W. Chen, M. Agio, and V. Sandoghdar, *Phys. Rev. Lett.* **108**, 233001 (2012). [2] S. Vassant, B. Hoffmann, K. Matsuzaki, X.-W. Chen, S. Christiansen, S. Götzinger, and V. Sandoghdar, *in preparation.*

Q 62.60 Thu 17:00 C/Foyer

Experimental realization of an optical antenna designed for collecting 99% of photons from a quantum emitter — •Xiao-Liu Chu[1,2], Thomas Brenner[1,3], Xue-Wen Chen[1,2], Yagnaseni Ghosh[4], Jennifer Hollingsworth[4], Vahid Sandoghdar[1,2], and Stephan Götzinger[2,1] — [1]Max Planck Institute for the Science of Light, 91058 Erlangen, Germany — [2]Department of Physics, Friedrich Alexander University of Erlangen-Nürnberg, 91058 Erlangen, Germany — [3]Institute of Physics and Astronomy, Universityof Potsdam, 14476 Potsdam-Golm, Germany — [4]Materials Physics and Applications: Center for Integrated Nanotechnologies, Los Alamos National Laboratory, Los Alamos, New Mexico 87545, USA

We have recently theoretically investigated a planar metallo-dielectric antenna that is designed to convert the dipolar radiation of an arbitrarily oriented emitter to a directional beam with more than 99% efficiency. Here, we present the fabrication and characterization of such an antenna using a single colloidal quantum dot (CdS/CdSe)as single-photon source. The antenna consists of a multilayer architecture with stepwise change in the refractive index. Single photons emitted by a quantum dot sandwiched in between high and low refractive index layers are channeled into the high index substrate and collected by a standard microscope objective. This system serves as a stable and ultra-bright source of single photons that is highly desirable for information processing, metrology and other emerging quantum technologies.

[1] X.-W. Chen *et al.*, Opt. Lett. **36**, 3545 (2011)
[2] X.-L. Chu *et al.*, Optica **1**, 203 (2014)

Q 62.61 Thu 17:00 C/Foyer

Interfacing Light and Single Molecules in a Dielectric Nanoguide — •Pierre Türschmann[1], Harald. R. Haakh[1], Tobias Utikal[1], Stephan Götzinger[2,1], and Vahid Sandoghdar[1,2] — [1]Max Planck Institute for the Science of Light (MPL), D-91058 Erlangen, Germany — [2]Department of Physics, Friedrich Alexander University of Erlangen-Nürnberg, D-91058 Erlangen, Germany.

The experimental realization of an efficient interface between propagating photons and a scalable number of single quantum emitters is one of the major challenges at the forefront of quantum optics. Such a system would allow one to study intriguing many-body effects relying on cooperative phenomena and polaritonic excitations. Here, we present a solid-state platform, where we demonstrate the coherent coupling of single molecules to a highly confined mode in a dielectric waveguide of subwavelength diameter [1]. Our current nanocapillary-based system can deliver coupling efficiencies (β) up to 18%. We discuss our experimental results, the prospects of our approach, and the ongoing efforts for achieving higher coupling efficiencies in a chip-compatible geometry.

[1] S. Faez, P. Türschmann, H.R. Haakh, S. Götzinger, and V. Sandoghdar, *Phys. Rev. Lett.* **113** , 213601 (2014).

Q 62.62 Thu 17:00 C/Foyer

Chiral photon emission beyond paraxial approximation — •Stefan Walser, Jan Petersen, Jürgen Volz, and Arno Rauschenbeutel — Atominstitut - TU Wien

Electromagnetic radiation is typically considered as a fully transverse polarized wave, where the electric field is perpendicular to the propagation direction. However this is only valid in the paraxial approximation. Beyond this approximation in highly confined light fields non-transversal polarization components appear. Together with the transversal components this leads to local circular polarization where the sense of rotation (spin) depends on the propagation direction. Thus the internal spin of photons gets coupled to their orbital angular momentum. Using this spin-orbit interaction of light we break the mirror symmetry of the scattering of light. Positioning a gold nano-particle on the surface of a nano-photonic waveguide we thereby realize a chiral waveguide coupler in which the handedness of the incident light determines the propagation direction in the waveguide [1].

[1] Jan Petersen et al., *Chiral nanophotonic waveguide interface based on spin-orbit interaction of light*, Science 346, 6205 (2014)

Q 62.63 Thu 17:00 C/Foyer

Single-mode waveguide for evanescent broadband coupling — •Lars Liebermeister[1], Niko Heinrichs[1], Peter Fischer[1], Martin Zeitlmair[1], Florian Böhm[1], Lukas Worthmann[1], Harald Weinfurter[1,2], and Markus Weber[1,2] — [1]Ludwig-Maximilians-Universität, München — [2]Max-Planck-Institut für Quantenoptik, Garching

Efficient coupling of single quantum emitters to single optical modes is of high importance for the realization of integrated optical devices for applications in quantum information science as well as in the field of sensing. Here we present the design and fabrication of a platform for on-chip experiments based on dielectric optical single-mode waveguides (Ta_2O_5 on SiO_2). The design of the waveguide is optimized for broadband evanescent coupling to a single quantum emitter and low-loss single-mode photon guidance. Additionally, efficient coupling to standard single-mode fibers is achieved with inverted tapers.

Coupling to a quantum emitter placed on the waveguide could be as high as 34% for emission wavelengths from 600nm to 800nm. First test samples exhibit propagation loss below 1.8dB/mm and off-chip coupling to standard single mode fibers reached efficiency exceeding 57%. These results are promising for efficient coupling of emitters like the NV-center to a single optical mode and running multi-wavelength excitation and emission schemes in on-chip experiments.

Q 62.64 Thu 17:00 C/Foyer

Interfacing single molecules with nanofibers — •Hardy Schauffert, Sarah Skoff, and David Papencordt — Institut für angewandte Quantenoptik, TU Wien

Tapered optical fibers with a nanofiber waist have proven to be a highly sensitive tool for surface spectroscopy. A route towards extending the range of applications to the single-molecule level is to deposit dye-doped organic crystals of sub-micron size, in our case terrylene-doped p-Terphenyl, onto the nanofiber and to interface them with the evanescent field of the fiber-guided light. In previous studies different ways of deposition and preparation of the crystal have been developed, so that we are able to efficiently detect single molecules by fluorescence excitation spectroscopy . We will present the most recent results and show that the lifetime limited linewidth at cryogenic conditions and the strong Zero-Phonon-Line of Tr together with the nanofiber interface make this system a good candidate for a single photon source in the future.

Q 62.65 Thu 17:00 C/Foyer

Nanodiamonds with singe nitrogen vacancy centres in laser-written microstructures — •Bernd Sontheimer[1], Qiang Shi[2], Johannes Kaschke[2], Tanja Neumer[1], Joachim Fischer[2], Andreas W. Schell[1], Martin Wegener[2], and Oliver Benson[1] — [1]AG Nanooptik, Humbodt-Universität zu Berlin, Germany — [2]DFG-Center for Functional Nanostructures, Karlsruhe Institute of Technology (KIT), Germany

Hybrid integration of nano-sized quantum emitters in photonic structures can be achived by random methods or by nanomanipulation techniques. We report on our recent progress using another approach. In our method, the nanodiamonds are embedded in a photoresist, which is subsequently structured [1]. This allows for fabrication of a variety of different structures, such as resonators and waveguides coupled to single emitters. By pre-characterizing the emitter's properties and position, such structures can be fabricated in a highly controlled way [2].

[1] Schell et al.. Sci. Rep. 3, 1577 (2013)
[2] Schell et al., Appl. Phys. Lett. (accepted)

Q 62.66 Thu 17:00 C/Foyer

Resonant excitation of nitrogen-vacancy centers at room temperature — •Martin Zeitlmair[1], Lars Liebermeister[1], Niko Heinrichs[1], Florian Boehm[1], Peter Fischer[1], Lukas Worthmann[1], Harald Weinfurter[1,2], and Markus Weber[1,2] — [1]Ludwig-Maximilians-Universität, München — [2]Max-Planck-Institut für Quantenoptik, Garching

The development of efficient single-photon sources is a crucial prerequisite for future applications in applied physical and quantum information science. Our interest lies in the evanescent coupling of a single defect center in diamond to dielectric nanostructures like the tapered region of an optical fiber. Previous studies on a single NV-center coupled to a tapered optical fiber showed a coupling efficiency of 10% [1], however with the drawback of strong unwanted fiber fluorescence caused during off-resonant excitation at 532nm. In this context, resonant excitation at the zero-phonon line at 637nm promises reduced background fluorescence.

Here, we present first room temperature experiments on the pulsed resonant excitation of a single NV-center with pulse lengths of a few nanoseconds. As excitation also populates the undesired neutral charge state, which cannot be addressed via resonant excitation, periodic off-resonant reinitialization of the negative charge state is applied. Clear antibunching characteristics in the autocorrelation measurement indicate the possible application of this resonant excitation scheme for efficient single-photon sources with low background fluorescence.

[1] Liebermeister et. al., APL 104(3) (2014): 031101

Q 62.67 Thu 17:00 C/Foyer

Why you should be interested in the silicon vacancy centre in diamond — •Lachlan J. Rogers and Fedor Jelezko — Institute for Quantum Optics and IQST, Ulm University, Ulm, Germany

The negative silicon vacancy (SiV^-) colour centre in diamond is currently experiencing a flurry of research attention. It has emerged from comparative obscurity to become one of only three diamond colour centres that enable coherent manipulation of individual spins. This poster reviews the recent breakthroughs that established SiV as an exceptional source of indistinguishable single-photons, and then as an optically-accessible spin qubit system. The simultaneous presence of these two abilities is the main reason for you to be interested in the SiV centre. If you've wondered what all the fuss is about then now is the perfect time to get "up to speed" on the silicon vacancy centre!

Q 62.68 Thu 17:00 C/Foyer

Investigating Optical Stability of Single Vacancy Centres in Nanodiamonds — •Andrea Kurz[1], Lachlan J. Rogers[1], Kay D. Jahnke[1], Uwe Jantzen[1], Clemens Schäfermeier[2], Andreas Dietrich[1], Fedor Jelezko[1], and Alexander Kubanek[1] — [1]Ulm University, Deutschland — [2]Technical University of Denkmark, Denmark

The silicon vacancy colour centre (SiV) in diamond has remarkable properties as single photon emitter. It has a strong zero phonon line that contains 70% of the emitted photons, and only a weak phonon side-band.

Recently SiV centres were found to remain fluorescent in nanodimaonds as small as 1.7nm, which is smaller than any reported nanodiamonds exhibiting nitrogen-vacancy fluorescence. This suggests that SiV is more robust against crystal distortions or surface interactions than the nitrogen vacancy centre(NV) is, and suggests it would make an excellent fluorescent marker for bioimaging. However, we have observed blinking from SiV in nanodiamonds but not from SiV in bulk diamond.

Here we investigate this change in optical stability by examining the effects of various surface treatments on the fluorescence of SiV in nanodiamonds of size 20-200 nm. The procedures are similar to those used previously to study the surface effects of NV centres in nanodiamonds.

Q 62.69 Thu 17:00 C/Foyer

non-classical emission from CdSe/CdS dot-in-rods and their clusters — •Luo Qi[1,4], Lukas Lachman[2], Mathieu Manceau[3], Maria Chekhova[1,4,5], Radim Filip[2], Elisabeth Giacobino[3], and Gerd Leuchs[1,4] — [1]Max-Planck Institute for the Science of Light, G.-Scharowsky Str 1/Bldg 24, 91058 Erlangen, Germany — [2]Department of Optics, Palacky University, 17. listopadu 1192/12, 771 46 Olomouc, Czech Republic — [3]Laboratoire Kastler Brossel, Université Pierre et Marie Curie, Ecole Normale Supérieure, CNRS, 4 place Jussieu, 75252 Paris Cedex 05, France — [4]Universität Erlangen-Nürnberg, Staudtstraße 7/B2, 91058 Erlangen, Germany — [5]M. V. Lomonosov Moscow State University, 119992 GSP-2 Moscow, Russia

Colloidal CdSe/CdS dots-in-rods (DRs) quantum dots are one of the most promising types of single-photon emitters, due to their numerous advantages: room temperature applications, low cost synthesis, emission with high degree of polarization, and compatibility with planar nanofabrication technology. DRs can merge into clusters, which also can be used for quantum information processes, since they emit non-classical light, which shows possible applications as multi-photon sources. We are currently investigating the properties of the non-classical emissions from CdSe/CdS DRs and their clusters by measuring the high-order correlation functions with a spatially resolving intensified CCD camera and an effective data processing approach, which brought us into the average single-photon detection level.

Q 62.70 Thu 17:00 C/Foyer

Single molecule localization microscopy of chromatin structure using standard DNA dyes — Aleksander Szczurek[1], •Christoph Cremer[1,2,3], and Udo Birk[1,3] — [1]Institute of Molecular Biology, Mainz — [2]Institute for Pharmacy and Molecular Biotechnology, University of Heidelberg — [3]Kirchhoff Institute for Physics, Heidelberg University, Heidelberg

In order to investigate DNA-chromatin structure, one may employ optical microscopy as a method of choice, due to feasibility. However, conventional light optical imaging approaches suffer from diffraction of the visible wavelengths used, limiting the resolution of structures to about 200 nm laterally and 600 nm axially. To overcome this shortcoming, recently novel visible light super-resolution imaging approaches have emerged. Presently, particulrly Structured Illumination Microscopy (SIM) and Single Molecule Localisation Microscopy (SMLM) have been established as useful approaches in investigations of eukaryotic cell nucleus. Here we present a novel application of commonly used DNA dyes in order to obtain nuclear DNA density maps with high optical and structural resolution. The approach presented is based on photoconversion to the green-emitting form of these dyes that later may undergo a process of switching under high intensity blue light [1][2]. In mammalian cell nuclei, this technique yielded a single molecule localisation precision in the order of 15 - 30 nm, corresponding to an optical resolution of roughly 40 - 70 nm.

Q 62.71 Thu 17:00 C/Foyer

Angstrom-Resolution Cryogenic Localization Microscopy — •Siegfried Weisenburger, Luxi Wei, and Vahid Sandoghdar — Max Planck Institute for the Science of Light and Department of Physics, Friedrich-Alexander University Erlangen-Nürnberg, 91058 Erlangen

The significance of super-resolution microscopy beyond the diffraction limit was recognized by the Nobel Prize in Chemistry in 2014. One of the super-resolution techniques is based on finding the position of single fluorophores by determining the center of their point-spread functions with arbitrary localization precision, whereby the latter depends on the available signal-to-noise ratio. We recently demonstrated Angstrom localization precision made possible by the substantial improvement of the molecular photostability at cryogenic temperatures [1]. We have now demonstrated a cryogenic colocalization microscopy method with two fluorophores on the backbone of a double-stranded DNA [2]. By measuring the separations of fluorophore pairs placed at various design positions, we verify the feasibility of cryogenic distance measurement with sub-nanometer accuracy. We discuss the challenges of our methodology and our progress towards the measurement of intramolecular distances in proteins and other biomolecules.

[1] S. Weisenburger, B. Jing, A. Renn, and V. Sandoghdar, Proc. SPIE 8815, 88150D (2013).
[2] S. Weisenburger, B. Jing, D. Hänni, L. Reymond, B. Schuler, A. Renn, and V. Sandoghdar, ChemPhysChem 15, 763 (2014).

Q 62.72 Thu 17:00 C/Foyer

Light scattering in hybrid optomechanical systems in diamond — •Luigi Giannelli, Giovanna Morigi, and Marc Bienert — Theoretische Physik, Universität des Saarlandes, Campus E2 6, D 66123 Saarbrücken, Germany

We theoretically investigate a hybrid optomechanical crystal in diamond consisting of an optical cavity, a mechanical resonator and a single nitrogen vacancy (NV) center. This work is based on [1], adapted for a crystal cavity. The electronic degree of freedom of the NV center, a single mode of the cavity's electromagnetic field and a single vibrational mode of the mechanical oscillator are mutually coupled by dipole interaction, radiation forces and via the strain field associated with the mechanical vibrations. For such a composite quantum system we study the light scattering in the regime of weak mechanical coupling, which can lead to laser cooling of the mechanical mode. We identify the parameters regimes, where cooling becomes possible and reveal the underlying dynamical processes whose characteristics manifest themselves in the spectrum of the scattered light.

[1] K. V. Kepesidis, S. D. Bennett, S. Portolan, M. D. Lukin, and P. Rabl. "Phonon cooling and lasing with nitrogen-vacancy centers in diamond". In: Physical Review B 88 (Aug. 2013), p. 064105.

Q 62.73 Thu 17:00 C/Foyer

Towards x-ray optomechanics — •Luling Jin[1], Yong Li[2], and Jörg Evers[1] — [1]Max-Planck-Institut für Kernphysik, Heidelberg — [2]Computational Science Research Center CSRC, Peking, China

The feasibility of extending optomechanics to the x-ray frequency range is discussed. For this, we analyze hybrid optomechanical systems combining elements operating in the optical region [1] and the x-ray region [2]. We find that an optomechanical coupling can be established between the x-ray photons and the visible light, which can be used to detect properties of the x-ray light and its influence on the mirror motion.

[1] M. Aspelmeyer, T. J. Kippenberg, F. Marquardt, arXiv:1303.0733v1 [cond-mat.mes-hall]

[2] K. P. Heeg et al, Phys. Rev. Lett. 111, 073601 (2013)

Q 62.74 Thu 17:00 C/Foyer

Hybrid optomechanics with ultracold atoms and a nanomechanical membrane — •Tobias Kampschulte[1], Andreas Jöckel[1], Aline Faber[1], Lucas Beguin[1], Berit Vogell[2], Klemens Hammerer[3], Peter Zoller[2], and Philipp Treutlein[1] — [1]Universität Basel, Departement Physik — [2]Universität Innsbruck, IQOQI — [3]Universität Hannover, Institut für theoretische Physik

Hybrid systems in which a mechanical degree of freedom is coupled to a microscopic quantum system promise to enable control and detection of mechanical motion on the quantum level. This will create new options for precision sensing and might allow fundamental tests of quantum mechanics. In our experiment we couple the motion of an atomic ensemble to the vibrations of a Si_3N_4 membrane. We have exploited this coupling to cool the fundamental vibrational mode of the membrane from room temperature to 650±330 mK [1]. Recently we repeated and extended our measurements in a more compact and stable membrane-cavity system, whose size is small enough for cryogenic precooling of the membrane. Further we are developing a new coupling scheme to the internal states of the atoms. This will allow us to use higher frequency oscillators, which are affected less by laser noise. Moreover the internal states of the atoms can be prepared and detected with a higher precision than the motional states. With the technical and conceptional changes, ground state cooling and quantum control of the mechanical oscillator should come within reach.

[1] A. Jöckel *et al.*, Nature Nanotechnology (2014).

[2] B. Vogell *et al.*, Phys. Rev. A 87, 023816 (2013).

Q 62.75 Thu 17:00 C/Foyer

Nano-scale rotor driven by single-electron tunneling — •Alan Celestino, Alexander Eisfeld, and Alexander Croy — MPIPKS, Dresden, Germany

We study theoretically the dynamics and the electronic transport in a nano-scale rotor. The rotor is driven by electron tunneling in the Coulomb-blockade regime. We show that a static bias can lead to self-excitation of intermittent oscillatory/rotatory or continuous rotational motion. We establish the connection between the dynamical regimes and the current through the device. The relevant device's parameters are identified and we study the dynamics' dependence on these parameters. Notably, in the intermittent regime we found a negative differential conductance window. The current-voltage characteristics can be used to infer details of the surrounding environment which is responsible for damping. Finally, we show how to break the system's symmetry in order to recast it as a rectifier.

Q 62.76 Thu 17:00 C/Foyer

Design of an XUV and soft X-ray split-and-delay unit for FLASH II — •Sebastian Roling, Björn Siemer, Frank Wahlert, Michael Wöstmann, and Helmut Zacharias — Westfälische Wilhelms-Universität Münster

An XUV and soft X-ray split-and-delay unit is designed that enables time-resolved experiments covering the whole spectral range of FLASH II from $h\nu = 30$ eV to about 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 to choose 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 $h\nu = 30$ eV and 600 eV at a grazing angle $\theta = 1.8°$. With a Pt-coating a transmission of T $>$ 13% will be possible for photon energies up to $h\nu = 1500$ eV. For a future upgrade of FLASH II the grazing angle can be changed to $h\nu = 1.3°$ in order to cover a range up to $h\nu = 2500$ eV.

Q 62.77 Thu 17:00 C/Foyer

A split-and-delay unit for the European XFEL: Enabling hard x-ray pump/probe experiments at the HED instrument — •Tobias Hovestädt[1], Sebastian Roling[1], Karen Appel[2], Stefan Braun[3], Peter Gawlitza[3], Liubov Samoylova[2], Harald Sinn[2], Björn Siemer[1], Frank Siewert[4], Frank Wahlert[1], Michael Wöstmann[1], and Helmut Zacharias[1] — [1]Westfälische Wilhelms-Universität Münster — [2]European XFEL GmbH, Hamburg — [3]Fraunhofer IWS, Dresden — [4]Helmholtz-Zentrum Berlin für Materialien und Energie, Berlin

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 $h\nu = 20$ 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 set-up is based on geometric wavefront beam splitting, which has successfully been implemented at an autocorrelator at FLASH. The x-ray FEL pulses will be split by a sharp edge of a silicon mirror coated with Mo/B4C and W/B4C multilayers. Both partial beams will 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. For a photon energy of hν = 20 keV a grazing angle of $\theta = 0.57°$ has to be set, while for $h\nu =$ keV the angle amounts to 2.3°.

Q 62.78 Thu 17:00 C/Foyer

Temporal coherence properties of FLASH at $\lambda = 31.7$ nm — •Paul Möllers[1], Sebastian Roling[1], Peter Üffink[1], Sven Toleikis[2], Michael Wöstmann[1], and Helmut Zacharias[1] — [1]Westfälische Wilhelms-Universität Münster — [2]DESY, Hamburg

Free electron lasers (FEL) based on Self-Amplified Spontaneous Emission (SASE) emit partially coherent radiation that enables among others the performance of diffractive imaging experiments. Especially for these experiments a precise knowledge of the coherence properties is of utmost importance. With the split-and-delay unit (SDU) at beamline BL2 at FLASH the temporal coherence at $\lambda = 31.7$ nm is measured for the present accelerator configuration including a 3rd harmonic phase shifter. For the generation of saturated SASE radiation electron bunches with a bunch charge of $Q = 0.33$ nC are accelerated to E = 457.6 MeV. The FLASH pulses with a pulse energy of 16.5 μJ are split by the sharp edge of a wavefront beam splitter in the SDU. One of the partial beams can be delayed with respect to the other by moving the delay stage. Both partial beams are then overlapped on a CCD-camera. At zero delay interference fringes occur with a visibility of $V = 0.82$. The visibility decreases as expected when the delay of one beam with respect to the other is increased. A Gaussian function can be fitted to the data yielding a coherence time of $\tau_c = 4.7$ fs.

Q 62.79 Thu 17:00 C/Foyer

Local symmetries and invariants in wave scattering — •Christian Morfonios[1], Panayotis Kalozoumis[1], Fotis

Diakonos[2], and Peter Schmelcher[1,3] — [1]Centre for Optical Quantum Technologies, Hamburg University, Germany — [2]Department of Physics, Athens University, Greece — [3]The Hamburg Centre for Ultrafast Imaging, Germany

Local inversion or translation symmetries in one dimension are shown to yield invariant currents that characterize wave propagation. These currents map the wave function from an arbitrary spatial domain to any symmetry-related domain, thereby generalizing the parity and Bloch theorems to the case of broken global symmetry. In particular, nonvanishing nonlocal invariants provide a systematic pathway to discrete global symmetry breaking [PRL 113, 050403]. Applied to locally mirror symmetric photonic multilayer systems, the invariants are used to classify scattering states according to the symmetry decomposition of the field profile, and perfectly transmitting resonances in aperiodic media are constructed from symmetry principles [PRA 88, 033857].

Q 62.80 Thu 17:00 C/Foyer

Optical beams with rotating transverse field distributions — •Falk Töppel[1,2], Andrea Aiello[1,2], and Gerd Leuchs[1,2] — [1]Max Planck Institute for the Science of Light, Günther-Scharowsky-Straße 1/Bldg. 24, 91058 Erlangen, Germany — [2]Institute for Optics, Information and Photonics, Universität Erlangen-Nürnberg, Staudtstraße 7/B2, 91058 Erlangen, Germany

The wave front of Laguerre-Gauss beams carrying orbital angular momentum, rotates at optical frequency around the propagation axis. By analogy, one may think of optical beams in free space whose transverse spatial field distribution rotates with time at variable speed. In fact, we propose two different implementations that allow to set the rotation frequency to different values ranging from some Hz to a few GHz. The study of these beams may extend the understanding of orbital angular momentum origin and effects. Here we consider the physical properties, as linear and angular momentum, of rotating beams and discuss potential applications.

Q 62.81 Thu 17:00 C/Foyer

Efficiency in WGM-Electro-Optic Modulators — •Alfredo Rueda[1,2,3], Florian Sedlmeir[1,2,3], Gerd Leuchs[1,2], and Harald G. L. Schwefel[1,2,3] — [1]Max Planck Institute for the Science of Light, 91058 Erlangen, Germany — [2]Intitute for Optics, Information and Photonics, University of Erlangen-Nuremberg, Germany — [3]SAOT, School of Advanced Optical Technologies, University of Erlangen-Nuremberg, Germany

The design of an efficient coherent link between telecom and microwave frequencies is an important task due to its impact in quantum communications.Nowadays there are many options to realize such systems, which require different schemes to describe them. We focus on second order non-linear interactions in an all resonant lithium niobate whispering gallery modes resonators. These systems are ideal due to their high quality factors at telecom frequencies ($Q \propto 10^8$) and their high $\chi^{(2)}$ constant. In order to describe the dynamic of these devices different detuning schemes of the optical and microwave fields will be theoretically investigated. We review the basic schemes in the classical and quantum description and calculate some of the relevant configurations. Of particular interest is the configuration for maximal photon conversion efficiency and maximal modulation intensity of each detuning scheme. From this, we can optimize this system to realize a single photon microwave detector or to improve its role as highly efficient light modulator.

Q 62.82 Thu 17:00 C/Foyer

Search for non-resonant field enhancement in an isotropic nonlinear optical medium — •Rojiar Penjweini[1,2], Marianne Bader[1,2], Markus Sondermann[1,2], and Gerd Leuchs[1,2] — [1]Max-Planck-Institute for the Science of Light, Erlangen, Germany — [2]Institute of Optics, Information and Photonics, University of Erlangen-Nuremberg, Erlangen, Germany

One mechanism for field enhancement is an imbalance in the amplitudes of incoming and outgoing dipole waves, which are usually of equal amplitude in the absence of an absorber. Here, we investigate the possibility to induce such an imbalance and hence field enhancement in a non-resonant nonlinear medium. More specific, we use a noble gas as an isotropic nonlinear medium and examine third harmonic generation. The dipole waves are generated by focusing radially polarized doughnut modes with a deep parabolic mirror. As an indication for field enhancement we look for an excess generation of third harmonic photons when increasing the solid angle. Besides the specific problem treated here, our setup opens the possibility for nonlinear optics in the strongly non-paraxial regime.

Q 62.83 Thu 17:00 C/Foyer

Ultrafast spatial shaping of femtosecond laser beams — •Tom Bolze and Patrick Nuernberger — Physikalische Chemie II, Ruhr-Universität Bochum, Universitätsstraße 150, 44801 Bochum

Femtosecond laser pulses and their temporal shaping are widely used in spectroscopy, material science and information technology. Spatial shaping of laser beams has also been demonstrated in multiple ways. However, changing the spatial distribution of a femtosecond pulse on the ultrafast timescale of the pulse itself is rather unexplored up to now.

We present a concept for this task, which involves a Mach-Zehnder-type setup. In one arm, a spiral phase plate transforms the incident Hermite-Gaussian (HG) laser beam into a Laguerre-Gaussian (LG) mode with orbital angular momentum (OAM) and a glass rod chirps the pulse in time. In the second arm, the transverse laser mode remains that of a HG beam and a femtosecond pulse shaper imprints the same amount of chirp but with the opposite sign onto the pulse. The beams from both interferometer arms are then recombined. The interference should resemble a corkscrew like motion of the intensity distribution around the beam axis on the timescale of the pulse. This can be visualized via a third "gate" pulse with perpendicular polarization which upconverts the spatial intensity distribution.

Q 62.84 Thu 17:00 C/Foyer

Frequency-Resolved Optical Gating: Multiple Pulse Reconstruction and Error Treatment — •Alexander Hause and Fedor Mitschke — Universität Rostock, Institut für Physik, Universitätsplatz 3, 18051 Rostock

Frequency-resolved optical gating (FROG) is the most established method to assess the amplitude-and-phase profiles of ultrashort laser pulses. Second harmonic generation (SHG) FROG is the most widely used version. However, for some complex pulse shapes it tends to produce false results. Here we discuss the reconstruction of multiple pulse structures, a situation in which SHG FROG frequently fails. We suggest a modification of the standard procedure and demonstrate that the rate of false results is significantly reduced. We also discuss reconstruction in the presence of noise. A procedure to obtain error bars is given; they allow to gauge the quality of the reconstruction.

Q 62.85 Thu 17:00 C/Foyer

Soliton Molecules in an Amplified Dispersion-Managed Fiber — Jan Froh, •Alexander Hause, and Fedor Mitschke — Universität Rostock, Institut für Physik, Universitätsplatz 3, 18051 Rostock

During the last couple of years it has been demonstrated that in dispersion-managed fibers bound states of several individual solitons, so-called soliton molecules, exist. They allow to code and transmit more than a single bit of information into one clock period. This is most welcome at a time when the demand of information-carrying capacity outgrows the supply. However, all previous experiments on soliton molecules were performed using passive fibers; attenuation due to fiber and splice loss had to be accepted – not a trivial issue in a nonlinear system. We have now integrated an optical amplifier into a dispersion-managed fiber in such a way that the dispersion allocation is only minimally perturbed while sufficient gain is provided to compensate for attenuation. First results on propagation of solitons and soliton molecules will be presented.

Q 62.86 Thu 17:00 C/Foyer

Improvements of a capillary Raman system for high-sensitivity gas analysis — •Simone Rupp[1], Timothy M. James[1], Andreas Off[1], Hendrik Seitz-Moskaliuk[1], and Helmut H. Telle[2] — [1]Institute of Technical Physics, Karlsruhe Institute of Technology, Germany — [2]Instituto Pluridisciplinar, Universidad Complutense de Madrid, Spain

Raman spectroscopy is an advantageous tool for the compositional analysis of gases: inline, non-contact, non-destructive and allowing to detect multiple species at once. Conventional 90° Raman systems have been set up by our group and were successfully developed towards a high precision and sensitivity. However, in order to enable real-time applications, e.g. in process control, or the detection of trace amounts of gases at sub-mbar total pressures, it is necessary to further increase the sensitivity beyond that of the conventional technique. One promising approach is the use of a highly-reflective, hollow capillary as the gas cell. The elongated scattering volume and the large light collection angle vastly enhance the Raman signal compared to conventional setups. However, current implementations suffer from a high fluorescence background due to interactions between laser light and glass from optical components. The resulting shot-noise limits the achievable sensitivity. We have investigated methods to minimize the fluorescence background in the setup whilst maximizing the collected Raman signal. This poster discusses these methods and shows that the resulting sensitivity enhancement goes along with other advantages like a higher mechanical stability or the possibility to use higher laser powers.

Q 62.87 Thu 17:00 C/Foyer

Relative Intensity Correction of Raman Spectrometers with NIST Standard Reference Material 2242 in 90° scattering geometry — •Magnus Schlösser, Simone Rupp, Tim Brunst, and Timothy M. James — Tritium Laboratory Karlsruhe, Institute of Technical Physics, Karlsruhe Institute of Technology

The US National Institute of Standards and Technology (NIST) has certified a set of Standard Reference Materials (SRM) which can be used to accurately determine the spectral sensitivity of Raman spectrometers. These solid state reference sources offer benefits like exact reproduction of Raman sampling geometry, simple implementation, or long-term stability. A serious drawback of these SRMs is that they are only certified in the back scattering (180°) configuration. In our work, we investigated if and how an SRM 2242 (applicable for 532 nm) can be employed in a 90° scattering geometry Raman system. We found and tested that the measurement procedure needs to be modified in order to comply with the certified uncertainty by NIST. This requires certain changes of the SRM illumination like considering the roughness of the laser entrance side surfaces, the appropriate polarization of the excitation beam andthe inner-filter effect. Finally, we present a round robin test performed to evaluate the systematic uncertainty of our procedure.

Q 62.88 Thu 17:00 C/Foyer

Bestimmung der Frequenzverschiebung und spektralen Breite der Brillouin-Streuung in Abhängigkeit von Temperatur und Salzgehalt — •Kerstin Lux, Pascal Lautz, David Rupp und Thomas Walther — TU Darmstadt, Institut für Angewandte Physik, Schlossgartenstraße 7, D-64289 Darmstadt

Um aus der Luft kontaktlos Temperaturprofile des Ozeans zu erstellen, entwickelt unsere Arbeitsgruppe ein flugtaugliches Brillouin-LIDAR-System. Dieses sendet Laserstrahlung in bis zu 100 m Meerestiefe und detektiert anschließend das rückgestreute Licht.

Die Messung der spektralen Verschiebung sowie der Linienbreite der inelastischen Brillouin-Streuung liefert zwei voneinander unabhängige Messgrößen, die eine laserbasierte Temperaturbestimmung des Meeres und die Ermittlung des Salzgehalts ermöglichen. Vorgestellt werden der verwendete Aufbau zur simultanen Bestimmung der Linienbreite und Frequenzverschiebung sowie erste Ergebnisse.

Des Weiteren werden am System geplante Weiterentwicklungen präsentiert, welche es ermöglichen sollen, dem Experiment weitere Informationen über den Ozean zu entnehmen.

Q 62.89 Thu 17:00 C/Foyer

Ein Brillouin-LIDAR zur Messung von Temperaturprofilen im Ozean — •David Rupp, Andreas Rudolf, David Jones und Thomas Walther — TU Darmstadt, Institut für Angewandte Physik, Schlossgartenstraße 7, D-64289 Darmstadt

Wir entwickeln ein flugtaugliches LIDAR-System zur Messung von Wassertemperaturen im Ozean bis zu 100 m Tiefe. Es soll eine flexible Alternative zu kontaktbasierten Messverfahren bieten. Als Indikator dient spontane Brillouin-Streuung, die eine temperaturabhängige Spektralverschiebung zum eingestrahlten Laserlicht aufweist.

Der Aufbau besteht aus einem ECDL-geseedeten, 5-stufigen, Ytterbium-dotierten Faserverstärker, der gepulst betrieben wird. Nach der anschließenden Frequenzverdopplung mit einem KTP-Kristall erhalten wir nahezu fourier-limitierte 10ns-Pulse mit einer Wiederholrate von bis zu 5kHz und etwa 0,5mJ Pulsenergie bei 543nm Wellenlänge. Unser Detektor wird durch einen atomaren Absorptionsfilter und einen ESFADOF-Kantenfilter, beide auf Rubidiumbasis, gebildet. Die bisherigen Wassertemperaturmessungen finden im Labor an einem Testozean statt, welcher aus temperierbaren Wasserrohren besteht.

Dieser Aufbau, dessen genaue Funktionsweise und die damit bisher im Labor am Testozean durchgeführten Messungen und Ergebnisse werden präsentiert, sowie die geplanten Weiterentwicklungen.

Q 62.90 Thu 17:00 C/Foyer

Aufbau eines Erbium-dotierten Faserverstärkers zur experimentellen Realisierung eines QKD-Netzwerkes — •Timothy Wohlfromm, Tobias Beck, Benjamin Rein, Sabine Euler und Thomas Walther — Institut für Angewandte Physik, AG Laser und Quantenoptik, TU Darmstadt, Schlossgartenstr. 7, 64289 Darmstadt

Das langfristige Ziel des Projekts ist die experimentelle Realisierung eines sternförmigen Netzwerkes, das den Quantenschlüsselaustausch mittels verschränkter Photonenpaare ermöglicht. Um die bestehende Telekommunikationsinfrastruktur nutzen zu können, werden diese bei der C-Band Wellenlänge von 1550 nm erzeugt und mittels WDMs an die Netzwerkteilnehmer verteilt. Zur Erzeugung der verschränkten Photonenpaare werden Fourier-limitierte Laserpulse mit einer Pulslänge im ns-Bereich und einer Wellenlänge von 775 nm benötigt. Diese Pulse werden durch Frequenzverdopplung der Pulse aus einem Er-dotierten Faserverstärker erzeugt. Der aktuelle Stand des Projekts wird vorgestellt.

Q 62.91 Thu 17:00 C/Foyer

Vermessung der Quanteneffizienz von GaAs-Photokathoden für die Testquelle Photo-CATCH — •Michael Michael, Joachim Enders, Martin Espig, Yuliya Fritzsche und Markus Wagner — TU Darmstadt, Institut für Kernphysik

Zur Erhöhung der Verfügbarkeit der Quelle polarisierter Elektronen am supraleitenden Darmstädter Elektronenbeschleuniger S-DALINAC wird zur Zeit ein Kathoden-Reinigungs- und -Testsystem aufgebaut ("Photo-CATCH", photo cathode activation, test and cleaning with atomic hydrogen), welches polarisierte Elektronen aus Strained-Superlattice-GaAs- und bulk-GaAs-Photokathoden erzeugt für Polarisations-, Hochstrom- und Laufzeitexperimente.

Zur Vermessung der wellenlängenabhängigen Quanteneffizienz von 400-1500 nm wird ein Superkontinuum durch die Einkopplung ultrakurzer Pulse eines Titan:Saphir-Lasers mittels einer nichtlinearen Glasfaser erzeugt. Dieses Weißlichtspektrum wird mit zwei Pellin-Broca-Prismen räumlich in schmalbandige Spektren mit einstellbaren Mittelwellenlängen umgewandelt. Wir berichten über die aktuellen Ergebnisse in Bezug auf Auflösung und Wiederholgenauigkeit des experimentellen Aufbaus.

Gefördert durch die DFG im Rahmen des SFB 634 und durch das Land Hessen im LOEWE-Zentrum HIC for FAIR.

Q 62.92 Thu 17:00 C/Foyer

Nanoscale vacuum-tube electronics devices triggered by few-cycle laser pulses — •Michal Hamkalo[1], Takuya Higuchi[1], M. Alexander Schneider[2], and Peter Hommelhoff[1] — [1]Lehrstuhl für Laserphysik — [2]Lehrstuhl für Festkörperphysik

Electrons emitted from metal nano-tips via above-threshold photoemission driven by few-cycle laser pulses were shown to be extremely confined in both time and space, even sensitive to the carrier-envelope-phase of a few-cycle laser pulse [1]. In this study, we propose a way to implement these spatiotemporally confined electrons into vacuum-tube electronics devices, instead of the thermally emitted electrons in the conventional tube electronics. This is beneficial to downsize the structures, as well as improving their operation speed. As a first step, we demonstrate a diode structure, where two metal nano tips work as a cathode and an anode, respectively. The electron emission yields of these tips are controlled by tailoring the optical near fields via tuning of their radii of curvature. Current status of the experiments to further decrease the distance between two tips with a better mechanical stability will be presented.

References

1. M. Krüger, M. Schenk and P. Hommelhoff "Attosecond control of electrons emitted from a nanoscale metal tip", Nature 475, 78-81 (2011)

Q 62.93 Thu 17:00 C/Foyer

Geometries and Materials for Laser-Based Particle Acceleration at Dielectric Structures — •Alexander Tafel[1], Joshua McNeur[1], Kenneth Leedle[2], Ang Li[1], James Harris[2], and Peter Hommelhoff[1] — [1]Department of Laserphysics, Friedrich-Alexander-Universität Erlangen-Nürnberg (FAU), Germany — [2]Department of Electrical Engineering, Stanford University, USA

Dielectric Laser Acceleration (DLA) has evolved quickly during the last few years. Successful experiments have been conducted with electron energies as low as 28 keV, accelerating gradients as high as 375 MeV/m and deflection angles of 8 mrad.[1],[2]. Here, we discuss anodic alumina honeycomb nanostructures that are being investigated for future DLA experiments. These nanostructures are periodic in two dimensions, resulting in field patterns and particle trajectories potentially leading to transverse microbunching. Moreover, the damage threshold of alumina in the NIR is high (4.9 J/cm^2)[3], enabling high accelerating field strengths in the range of 10 GV/m. Lastly, new laser-triggered electron field emission sources with ultrashort bunch lengths are under development at FAU and discussed.

[1] J. Breuer, P. Hommelhoff, Phys. Rev. Let., 111, 134803 (2013).
[2] K. Leedle et al., to be published.
[3] K. Soong et al., AIP Conference Proceedings, 1507, 511 (2012).

Q 62.94 Thu 17:00 C/Foyer

Silicon structures and 2 micron sources for DLA experiments — •Norbert Schönenberger[1], Joshua McNeur[1], Axel Rühl[2], Jonas Hammer[1], Ingmar Hartl[2], and Peter Hommelhoff[1] — [1]Friedrich Alexander Universität Erlangen-Nürnberg, 91054 Erlangen, Deutschland — [2]DESY, 22607 Hamburg, Deutschland

With the recent successful demonstration of Dielectric Laser Acceleration (DLA) of electrons using fused silica gratings and Ti:Sa lasers [1,2], we try to improve upon the current setup using silicon based structures and a 2 micron thulium fiber laser. Here, we show the modification of a commercial 5W thulium fiber laser to incorporate a Chirped Volume Bragg Grating (CVBG) for chirped pulse amplification (CPA). With this modification we achieve sub picosecond pulses in the >700nJ regime. Furthermore, we discuss the advantages of silicon based structures that will be used in conjunction with the new laser system and report on first experimental acceleration results.

1. Peralta et al 2013 Nature 503 91 2. Breuer and Hommelhoff 2013 Phys. Rev. Lett. 111 134803"

Q 62.95 Thu 17:00 C/Foyer

Dielectric Laser Acceleration of a Proton Beam — •Ang Li[1], Joshua McNeur[1], Johannes Depner[1], Jonas Hammer[1], Thorsten Kühn[1], and Peter Hommelhoff[1,2] — [1]Department of Physics, Friedrich Alexander University Erlangen-Nuremberg, Staudtstrasse 1, 91058 Erlangen, Germany — [2]Max Planck Institute of Quantum Optics, Hans-Kopfermann-Strasse 1, 85748 Garching, Germany

Dielectric Laser Acceleration, first demonstrated in 2013 by groups at Stanford [1] and Max Planck Institute of Quantum Optics (MPQ) [2], can potentially be used to accelerate low energy (∼10 MeV) protons. Here we introduce the concept of Dielectric Acceleration of protons, including basic theory, simulation results, and the planned experiment at The Tandem Accelerator at Friedrich Alexander University Erlangen-Nuremberg (FAU). Beam diagnostics at the Tandem Accelerator, and an outlook on future activities (e.g. focus the beam by using a triplet magnetic lens system, Dielectric Laser Acceleration with a 2 micron Thulium laser and a use of a 120 degree bending magnet as beam spectrometer, etc.) and potential long-term applications will be discussed.

[1] E. A. Peralta1 et al., Nature 503, 91 (2013)
[2] J. Breuer and P. Hommelhoff, Phys. Rev. Lett. 111, 134803 (2013)

Q 62.96 Thu 17:00 C/Foyer

Laser-driven current through graphene-nanogap tunnel junctions — •Christian Heide, Takuya Higuchi, Andreas Artinger, Konrad Ullmann, Heiko B. Weber, and Peter Hommelhoff — Department Physik, Friedrich-Alexander-Universität Erlangen-Nürnberg

When a nanometer-scale gap is formed between two conducting nanostructures, the quantum tunneling of electrons dominates the transport properties of the junction, providing unique opportunities in electronics such as tunnel diodes. Recently, steering of the electron tunneling process by the electric field of few-cycle femtosecond laser pulses was demonstrated at the surface of a metal nanotip [1]. In this presentation, we show first results on the transport properties of graphene nanogap tunneling junctions under illumination of few-cycle laser pulses, where a similar laser-field-driven tunneling is expected. We observed an increase in the tunneling current through the nanogap under the laser illumination, which can be regarded as photon-assisted tunneling process.

[1] M. Krüger, M. Schenk and P. Hommelhoff, Nature 475, 78-81(2011).

Q 62.97 Thu 17:00 C/Foyer

Phase-resolved photoemission from metal nanotips at infrared wavelengths — •Michael Förster, Timo Paschen, Sebastian Thomas, and Peter Hommelhoff — Lehrstuhl für Laserphysik, Department Physik, FAU Erlangen-Nürnberg

Strong-field photoemission from metal nanotips has recently received much attention [1,2,3]. While it shares some of the physics with strong-field photoemission from gases and molecules, the excited near-field at tips also involves the field of nanooptics. This on the one hand leads to new effects, such as the suppression of quiver motion at mid- IR wavelengths [2], and on the other hand enables to use attosecond physics to measure near fields at nanostructures with unprecedented precision [4].

In this contribution we show photoemission from nanotips using a 100 kHz carrier-envelope phase (CEP)-stable few-cycle source around 1.8 um [5], similar to [3]. High pulse energies and infrared wavelengths enable us to study CEP effects in photoemission in the tunnelling regime. We discuss our results using theoretical models.

[1] M. Krüger et al., Nature 475, 79 (2011).
[2] G. Herink et al., Nature 483, 190 (2012).
[3] B. Piglosiewicz et al., Nature Photonics 8, 37 (2014).
[4] S. Thomas et al., Nano Lett. 13, 4790 (2013).
[5] C. Homann et al., Opt. Lett. 37, 1673 (2012).

Q 62.98 Thu 17:00 C/Foyer

Detecting Harmonic Generation from a Metal Nanotip — •Ella Schmidt, Michael Förster, Timo Paschen, and Peter Hommelhoff — Lehrstuhl für Laserphysik, Department Physik, FAU Erlangen-Nürnberg

Strong-field photoemission from metal nanotips has recently been studied intensively (see eg [1],[2]). In the resulting energy spectrum of the emitted electrons a plateau region can be observed due to rescattering. In the analogous atomic case, electrons that are driven back to the parent ion can also recombine, leading to high harmonic generation. Here, we explore the possibility of harmonic generation at metal tips, where second harmonic generation has previously been observed [3].

We present a setup that enables the observation of harmonic generation from a metal nanotip. 6-fs laser pulses from a Titanium:sapphire laser oscillator are focused on a sharp tungsten nanotip and the harmonics are observed with a photomultiplier.

[1] M. Krüger et al., Nature **475**, 78 (2011).
[2] G. Wachter et al., Phys. Rev. B **86**, 035402 (2012).
[3] A. Bouhelier et al. Phys. Rev. Lett. **90**, 013903 (2003).

Q 62.99 Thu 17:00 C/Foyer

Design of a novel microwave-chip electron beam splitter — •Philipp Weber, Jakob Hammer, Sebastian Thomas, and Peter Hommelhoff — Department für Physik, Friedrich-Alexander-Universität Erlangen-Nürnberg, Staudtstrasse 1, 91058 Erlangen

We study free electrons in a microwave driven quadrupole guide [1, 2] in order to build a new and well-controllable electron-based quantum system. Here we present design and experimental demonstration of a new beam splitter for slow electrons based on a planar microwave chip. The transverse confinement for electron guiding is generated by a planar surface-electrode chip that is driven at microwave frequencies in the GHz range.

We have experimentally realized a planar chip that smoothly transforms the transverse guiding potential from a harmonic single well into a double well potential, thereby separating the 1eV electron beam into two output beams [3]. We will discuss further steps towards the demonstration of coherent splitting of an electron beam with this technique.

[1] J. Hoffrogge, R. Fröhlich, M. Kasevich and P. Hommelhoff, Phys. Rev. Lett. 106, 193001 (2011).
[2] J. Hoffrogge and P. Hommelhoff, New. J. Phys. 13, 095012 (2011).
[3] J. Hammer, S. Thomas, P. Weber and P. Hommelhoff, arXiv1408.2658.

Q 62.100 Thu 17:00 C/Foyer

Potassium Spectroscopy on a Sounding Rocket — •Kai Lampmann[1], Ortwin Hellmig[5], Achim Peters[2], Patrick Windpassinger[1,5], and The KALEXUS Team[1,2,3,4] — [1]Institut für Physik, Johannes Gutenberg-Universität, Mainz — [2]Institut für Physik, HU Berlin — [3]Ferdinand-Braun-Institut, Leibniz-Institut für Höchstfrequenztechnik, Berlin — [4]Institut für Quantenoptik, LU Hannover — [5]Institut für Laserphysik, U Hamburg

We present a laser spectroscopy system for the sounding rocket experiment KALEXUS. The KALEXUS experiment aims at demonstrating a completely autonomously operating laser spectroscopy system for quantum gas experiments in space. The whole system is designed to meet the stringent requirements of a sounding rocket launch and to provide redundancy for autonomous operation during the whole flight.

To this end, the spectroscopy module for laser frequency stabilization consists of special monolithic Zerodur components for guiding and overlapping the beams. We show ground based characterization measurements and tests for space qualification of the spectroscopy system and the fiber based splitting module, which connects the different functional units of the system and provides an offset frequency stabilization.

The KALEXUS project is supported by the German Space Agency DLR with funds provided by the Federal Ministry for Economic Affairs and Energy (BMWi) under grant number 50 WM 1345.

Q 62.101 Thu 17:00 C/Foyer

Intensity dependence of photoelectronic angular distributions — •Eike Lübking, Torsten Hartmann, Christoph Vorndamme, Uwe Morgner, and Milutin Kovacev — Institut für Quantenoptik, Leibniz Universität Hannover, Welfengarten 1, D-30167 Hannover, Germany

The intensity dependence of the angular and energy distributions of photoelectrons has been used to study the diverse processes involved in the 800-nm short-pulse ionization of xenon and argon, respectively, e.g. channel switching and resonant and non-resonant ionization [1, 2]. By looking at Rydberg resonances a relation between laser intensity in the focus and pulse energy could also be retrieved (intensity calibration).

In a first step we compare these results from literature, which were obtained with older photoelectron imaging spectrometers, to data obtained with a velocity map imaging spectrometer (VMI) utilized in our group. By using the high-power ultra-short laser sources available in our lab we are, in a second step, able to extend the study of intensity-related effects to a broader energy range. Additionally the ionization effects in other gases can be investigated.

[1] Schyja et al., PRA 57, 5, 3692 (1998) [2] Wiehle et al., PRA, 67, 063405 (2003)

Q 62.102 Thu 17:00 C/Foyer

Frequency comb referenced narrow-linewidth mid-IR laser spectrometer for high-resolution molecular spectroscopy — •Michael Hansen, Evangelos Magoulakis, Qun-Feng Chen, Ingo Ernsting, and Stephan Schiller — Heinrich-Heine-Universität Düsseldorf

We demonstrate a novel source for high-resolution molecular spectroscopy, a continous-wave quantum cascade laser (QCL) stabilized to a ULE cavity and referenced to an optical frequency comb. The MIR laser wave (5.4 μm) is upconverted to 1.2 μm by sum-frequency generation in an orientation-patterned GaAs crystal with the output of a standard high-power cw 1.5 μm fiber laser and subsequent amplification of the sum-frequency wave. The 1.5 μm laser is phase-locked to a standard Er:fiber based frequency comb. The upconverted light at 1.2 μm is stabilized to a high-finesse ULE cavity by feed-back control of the QCL's frequency.

Both the 1.5 μm and the 1.2 μm frequencies are simultaneously measured, and thus the frequency of the QCL can be calculated. Its frequency can be tuned by frequency tuning of the 1.5 μm wave.

Stabilization of the QCL to the ULE cavity results in sub-kHz linewidth and frequency determination with sub-kHz-level inaccuracy relative to an atomic frequency reference, in this case a hydrogen maser.

Q 62.103 Thu 17:00 C/Foyer

Laser induced fluorescence (LIF) measurements of skin tissue samples and improvement of the control system — •Ioannis Sianoudis[1], Eleni Drakaki[1], Ioannis Valais[2], Ioannis Karachalios[2], and Dimitrios Mathes[2] — [1]Department of Optics & Optometry, — [2]Department of Biomedical Engineering, Technological Educational Institute (T.E.I.) of Athens, 122 10 Athens, Greece, *e-mail: jansian@teiath.gr

Laser Induced Fluorescence (LIF) is a spectroscopic method, widely and successfully used as optical complementary techniques in medicine, in order to characterize chemical, physical and optical properties in skin tissue and to investigate changes for diagnostic purposes. The non-invasiveness of this method is a key advantage, making it an important tool in research and early diagnosis of skin lesions in screening tests with which a medical decision can be greatly facilitated. In this work, we present representative and characteristic LIF spectra of skin samples in situ, with a developed improved control system. This system is based on a RISC microcontroller technology, which was programmed to regulate the trigger between the laser pulse and spectrometer readings, adjust parameters like time delays, pulse intensity, energy etc accordingly and control the probe head. This developed microcontroller system provides a relative low-cost tool for LIF spectroscopy purposes, and it is a forerunner for the development and the composition of a mobile, clinical spectroscopic apparatus.

Q 62.104 Thu 17:00 C/Foyer

Probing and Modeling Optical Properties of High Band Gap Dielectrics Excited by Temporally Shaped Femtosecond Laser Pulses — •Nikolai Jelzow, Thomas Winkler, Christian Sarpe, Jens Köhler, Bastian Zielinski, Nadine Götte, Arne Senfleben, and Thomas Baumert — Institute of Physics and CINSaT, University of Kassel, Kassel, Germany Heinrich-Plett-Str. 40, D-34132 Kassel, tel. +49-561-804-4405, fax. -4452

The generation of a high density free electron plasma is the first step in the laser ablation of high bandgap materials. We have demonstrated that tailored ultrashort laser pulses are suitable for robust manipulation of optical breakdown, increasing the precision of ablation to one order of magnitude below the optical diffraction limit [1, 2]. In this study ionization mechanisms in water, as a prototype for high band gap materials, irradiated with bandwidth-limited and temporally asymmetric femtosecond laser pulses are investigated via ultrafast spectral interferometry [3]. Our measurements directly prove that temporally asymmetric shaped pulses control the ionization mechanisms through which the free electrons are generated in high band gap transparent materials. In our recent experiments, we extended the investigation by measuring transmission and reflection coefficient of the pump pulse in order to reveal spatial properties of the ionization process. The results obtained, correlate to results from material processing on solid samples. [1] L. Englert et al., Opt. Expr. 15, 17855 (2007), [2] JLA 24, 042002 (2012); [3] C. Sarpe et al., NJP 14, 075021 (2012)

Q 62.105 Thu 17:00 C/Foyer

GaAs/AlGaAs Phase Modulator for 780 nm Lasers — •Bassem Arar[1], Hans Wenzel[1], Reiner Güther[1], Olaf Brox[1], Andre Maassdorf[1], Andreas Wicht[1,2], Achim Peters[1,2], Markus Weyers[1], Götz Erbert[1], and Günther Tränkle[1] — [1]Ferdinand-Braun-Institut, Leibniz-Institut für Höchstfrequenztechnik, Gustav-Kirchhoff-Str. 4, 12489 Berlin, Germany — [2]Humboldt-Universität zu Berlin, Institut für Physik, Newtonstr. 15, 12489 Berlin, Germany

Micro-integrated laser systems operating at the wavelength of 780 nm have recently received increasing attention. This is due to the growing efforts towards building very compact photonic components for Rubidium and Potassium atomic spectroscopy in the field and in space. Phase modulators are central building blocks in these devices. Integration of phase modulators into hybrid laser and spectroscopy modules provides very compact and robust systems. We present a GaAs/AlGaAs W-shaped phase modulator for the wavelength of 780 nm with very low optical losses (1.4 dB/cm). The modulation efficiency is determined to 16 Deg/(Vmm) using the FP interference method. The measured modulation bandwidth with a direct 50 Ohm source is about 30 MHz. The reduction of the modulator capacitance by one to two orders of magnitude seems feasible in the future so that the modulator could provide access to modulation frequencies beyond 1 GHz with direct driving. 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 50WM1141.

Q 62.106 Thu 17:00 C/Foyer

Photonic Lanterns - Characterisation for applications in Astrophotonics — •Katjana Ehrlich, Dionne Haynes, Jean-Christophe Olaya, Roger Haynes, and Martin M. Roth — innoFSPEC, Leibniz-Institut für Astrophysik (AIP), Potsdam, Deutschland

On the one hand, seeing-limited star light from a telescope focal plane is injected into multi-mode fibres because of the coupling efficiency. On the other hand, fibre-based integrated photonics work in the single-mode regime and enable potential applications like spectral filtering with fibre Bragg gratings, integrated photonic spectrographs and fibre scrambler for high resolution spectroscopy. Photonic lanterns are devices that perform such a multi-mode (MM) to single-mode (SM) conversion. They are based on a taper transition which couples light between one multi-mode fibre to several single-mode fibres. The investigated device consists of 61 single-mode fibres. We study the transmission through a MM-SM conversion in high- and low-resolution experiments and find that the spectral information of the source is preserved and that photonic lanterns act as stable low noise systems regarding changes in the position of the input spot. We also spliced together two photonic lanterns and show that this MM-SM-MM converter generates less noise under mechanical perturbation. In the near field light distribution the photonic lanterns acts as an improved mode scrambler in comparison with a standard step-index multi-mode fibre.

Q 62.107 Thu 17:00 C/Foyer

Erzeugung von flachen, rechteckförmigen Frequenzkämmen mit beliebiger Bandbreite und variablem Frequenzabstand — •Stefan Preussler und Thomas Schneider — Institut für Hochfrequenztechnik, Technische Universität Braunschweig

In den letzten Jahren ist die Erzeugung von Frequenzkämmen rasant vorangeschritten, wodurch zuvor ungeahnte Möglichkeiten für die Messung von Naturkonstanten, Materie und Antimaterie sowie die hochgenaue Zeitmessung ermöglicht werden. Auch auf dem Gebiet der optischen Kommunikation, insbesondere im Bereich der WDMKommunikation und Radio-over-Fiber Systemen, ergeben unzählige Anwendungen. Besonders flache und rechteckförmige Frequenzkämme werden für die verzerrungsfreie Speicherung von optischen Datenpaketen, die Erzeugung von sinc-förmigen Nyquist-Pulsfolgen mit beispielloser Qualität, sowie für ideal rechteckig geformte photonische Mikrowellenfilter mit einstellbarem Passbandprofil benötigt.

Die vorgestellte Methode ermöglicht die Erzeugung von sehr flachen und rechteckförmigen Frequenzkämmen mit variabler Bandbreite, Anzahl der Linien sowie variablen Frequenzabstand. Dabei werden aus dem Spektrum eines modengelockten fs-Lasers verschiedene Linien mit dem nichtlinearen Effekt der stimulierten Brillouin Streuung extrahiert und die restlichen Linien durch Polarisationsfilterung unterdrückt. Anschließend erfolgt die Modulation mit gekoppelten Mach-Zehnder- Modulatoren. Bisher erzeugte Frequenzkämme erreichen Bandbreiten von $>$270 GHz mit Leistungsunterschieden zwischen den einzelnen Linien von $<$0.8 dB.