Q 58: Poster: Quantum Optics and Photonics IV

Time: Thursday 16:30–19:00 Location: Empore Lichthof

Q 58.1 Thu 16:30 Empore Lichthof

Quantum Friction and Markovianity — •Juliane Klatt[1], Stefan Yoshi Buhmann[1], and Diego A.R. Dalvit[2] — [1]Albert-Ludwig University, Freiburg, Germany — [2]LANL, Los Alamos, NM, USA

Quantum friction is the velocity-dependent force between two polarizable objects in relative motion, resulting from quantum-fluctuation mediated transfer of energy and momentum. Due to its short-ranged nature it has proven difficult to observe.

Attempts to determine the velocity-dependence of the drag experienced by an atom moving parallel to a surface have arrived at contradicting results. Scheel and Buhmann[1] predict a force linear in relative velocity v by employing the quantum regression theorem (QRT). Intravaia[2], however, predicts a v^3 power-law starting from a non-equilibrium fluctuation-dissipation theorem (FDT). The QRT approach assumes Markovianity, whereas the FDT does not but is restricted to stationary systems instead.

We employ the time-convolutionless expansion (TCL) for probing Markovianity and then study an atom flying towards a surface. We derive signatures of the relative motion in the atom's decay rates and level shifts, calculate the friction experienced by the atom and compare both to results obtained from time-dependent perturbation theory.

[1] S. Scheel and S. Y. Buhmann, Phys. Rev. A **80** (2009)
[2] F. Intravaia et al., Phys. Rev. A **89** (2014)

Q 58.2 Thu 16:30 Empore Lichthof

Casimir-Polder Interaction and Matter Wave Scattering — •Joshua Hemmerich and Stefan Buhmann — Physikalisches Institut Universität Freiburg, Germany

The interaction between electromagnetically neutral objects, atoms or molecules, has been a subject of study for more than a century. Often known as van der Waals force, this interaction can be formally understood within the context of quantum fluctuations of the electromagnetic field. We review the perturbative calculation of a general expression for the attractive Casimir-Polder potential for an atom interacting with an arbitrarily shaped dielectric body and apply it to the case of a dielectric sphere. The asymptotic behavior of this expression in the nonretarded and retarded limits, for small and large sphere radii and for a perfectly conducting sphere agrees with well-known historical results. We present numerical results for the interaction between a ground-state indium atom and a silicon-dioxide sphere. The results are used to study the impact of the Casimir-Polder force on matter-wave scattering. We are specifically interested in observations regarding the Poisson spot, where precise experiments are shown to lead to direct evidence of such an attractive Casimir-Polder potential.

Q 58.3 Thu 16:30 Empore Lichthof

Casimir–Polder Interaction and Matter Wave Scattering — •Joshua Hemmerich and Stefan Yoshi Buhmann — Freiburg Universitity, Freiburg, Germany

The interaction between electromagnetically neutral objects, atoms or molecules, has been a subject of study for more than a century. Often known as van der Waals force, this interaction can be formally understood within the context of quantum fluctuations of the electromagnetic field. We review the perturbative calculation of a general expression for the attractive Casimir–Polder potential for an atom interacting with an arbitrarily shaped dielectric body and apply it to the case of a dielectric sphere. The asymptotic behavior of this expression in the nonretarded and retarded limits, for small and large sphere radii and for a perfectly conducting sphere agrees with well-known historical results. We present numerical results for the interaction between a ground-state indium atom and a silicon-dioxide sphere. The results are used to study the impact of the Casimir–Polder force on matter-wave scattering. We are specifically interested in observations regarding the Poisson spot, where precise experiments are shown to lead to direct evidence of such an attractive Casimir–Polder potential.

Q 58.4 Thu 16:30 Empore Lichthof

Van der Waals interaction of Rydberg atoms in hollow-core fibers — •Helge Dobbertin[1], Harald R. Haakh[2], and Stefan Scheel[1] — [1]Universität Rostock, Rostock, Germany — [2]Max Planck Institute for the Science of Light, Erlangen, Germany

The presence of material boundaries modifies the van der Waals interactions between atoms and molecules [1]. In hollow-core fibers, it has been shown that there exist regimes in which the (nonresonant) interaction between ground-state atoms can be exponentially suppressed due to the lack of available waveguide modes [2]. Conversely, the presence of such modes for the relevant atomic transition frequencies may lead to an extended interaction range. Due to their extreme polarizability, Rydberg atoms are ideal candidates for strong dispersion interactions. The appearance of resonant contributions to the van der Waals interaction for excited atoms at their resonance frequencies provides an additional handle [3]. Here, we show how the waveguide modes in a cylindrical hollow-core fiber affect the van der Waals potential between highly-excited Rydberg atoms and, as a result, their Rydberg blockade.

[1] H. Safari *et al.*, Phys. Rev. A **74**, 042101 (2006).
[2] H.R. Haakh and S. Scheel, Phys. Rev. A **91**, 052707 (2015).
[3] H. Safari and M.R. Karimpour, Phys. Rev. Lett. **114**, 013201 (2015).

Q 58.5 Thu 16:30 Empore Lichthof

Magnetic Casimir-Polder Interaction and the Influence of Foucault currents — •Daniel Reiche[1,2], Francesco Intravaia[2], and Kurt Busch[1,2] — [1]Humboldt-Universität zu Berlin, Institut für Physik, AG Theoretische Optik & Photonik, Newtonstr. 15, 12489 Berlin, Germany — [2]Max Born Institute for Nonlinear Optics and Short Pulse Spectroscopy, Max-Born-Str. 2A, 12489 Berlin, Germany

Miniaturization is a major task for modern physics and for this atomic systems are promising candidates, e.g. for the implementation of quantum technologies. However, as atoms are trapped in a confined volume near macroscopic objects, phenomena like Casimir-Polder forces become important. In recent years, progress in experimental methods has revealed some not yet understood behaviors of these interactions, especially with respect to dissipation in material composing the macroscopic body.

To gain more insight we investigate the contribution of the Foucault current modes on the magnetic Casimir-Polder interaction for a two-level atom in front of a conducting half-space. Both, a local Drude model and a non-local material model are considered for the description of the half-space's permittivity. We analyze in detail the temperature dependence of some relevant thermodynamical properties of this contribution.

Q 58.6 Thu 16:30 Empore Lichthof

Decay properties of an atom coupled to a disordered 1D waveguide — •Michael P. Schneider[1], Christoph Martens[1], Tobias Sproll[1], and Kurt Busch[1,2] — [1]Max-Born-Institut, Max-Born-Str. 2A, 12489 Berlin, Germany — [2]Humboldt-Universität zu Berlin, Institut für Physik, AG Theoretische Optik & Photonik, Newtonstr. 15, 12489 Berlin

Single atoms coupled to one-dimensional (1D) waveguides are systems that are experiencing growing interest over the last years. They can be thought of as building blocks for quantum networks, where the entanglement between the atoms is distributed by means of single photons. These systems can be combined with structured waveguides, which exhibit a nonlinear dispersion relation, including band edges. In this case, the coupled atom-waveguide system supports an atom-photon bound state in the band gap. This is a polaritonic eigenstate of the system, which can be used for example to trap light.

We analyze the decay properties of a two-level system (TLS) coupled to a 1D waveguide with (fabricational) disorder. With the help of disorder-averaged Green's functions, also backed up by numerical calculations, we find that the atom-photon bound state is unstable for large enough disorder. Within the framework of a newly developed formalism we associate this effect to the disorder-induced smearing of the waveguides density of states. Additionally, we identify a special set of diagrams which are dominant for energies far away from the band edge. These diagrams introduce a new timescale in the decay process and thus render the system non-Markovian.

Q 58.7 Thu 16:30 Empore Lichthof

Atomic population transfer in integrated 1-D photonic structues — •Tobias Sproll[1], Christoph Martens[1], Francesco Intravaia[1], and Kurt Busch[1,2] — [1]Max-Born-Institut, Berlin, Germany — [2]Humboldt University, Berlin, Germany

As an important mechanism of population transfer, we discuss Foerster resonance energy Transfer (FRET) which has found wide applications in chemistry and biology. For example, FRET is used to measure interactions between proteins or distances inside them. Furthermore it is hoped that this effect leads to new opportunities for manipulating and storing information in optical circuits.

We analyze FRET in a model system consisting of a 1D optical wire and two atoms, modeled as 2- level systems. We analyze the spectrum of the problem using tools from Quantum Field Theory. From this results we argue that there are very general reasons that FRET in 1D is a truly non Markovian effect and is mediated by the polaritonic eigenmodes of our model system which occurrence strongly depends on the curvature and boundedness of the dispersion relation of the waveguide. This shows that linearization of the spectra may be insufficient to catch essential physical features of this systems.

A possible interesting application of our result could be in light harvesting complexes which are important for the design of organic solar cells.

Q 58.8 Thu 16:30 Empore Lichthof

Dynamics and interaction of two emitters embedded in a one-dimensional waveguide — •Christoph Martens[1], Tobias Sproll[1], Michael Peter Schneider[1], Francesco Intravaia[1], and Kurt Busch[1,2] — [1]Max Born Institute for Nonlinear Optics and Short Pulse Spectroscopy , Max-Born-Str. 2a, 12489 Berlin, Germany — [2]Humboldt-Universität zu Berlin, Institut für Physik, AG Theoretische Optik & Photonik, Newtonstr. 15, 12489 Berlin, Germany

Integrated, low-dimensional waveguiding structures with embedded emitters are promising candidates to form the basic building blocks of quantum-information processing networks. On this account, it is vital to study and understand the light-matter interactions within these structures on the quantum level.

In this contribution, we analyse the interaction of two two-level emitters embedded in a one-dimensional waveguide. We show how the dynamics of light emission and absorption is influenced by both polaritonic and cavity-like eigenstates of the whole system as well as by the mode structure of the waveguiding continuum. Furthermore, we reveal super- and subradiant states of the system.

Q 58.9 Thu 16:30 Empore Lichthof

Circuit-QED with left-handed superlattice metamaterials — •Anette Messinger, Bruno Taketani, and Frank K. Wilhelm — Theoretical Physics, Saarland University, 66123 Saarbrücken, Germany

Circuit QED deals with quantum phenomena in superconducting circuits, in which photons can interact with artificial qubits. With new circuit architectures one can reach new optical properties like nonlinear effects and left-handedness with promising applications for quantum computers. Recently, a quantum mechanical phase transition of the qubit's tunneling probability was predicted in a transmission line coupled to a left-handed circuit [1].

In this work, we investigate a superlattice of two alternating left-handed circuit cells instead of a normal left-handed circuit. This gives rise to a new energy band in which the density of modes can reach extremely high values, and with that, strong multimode coupling of the qubit is possible. Furthermore, we use adiabatic renormalization to find the effective tunneling element of the qubit. While in the previously proposed system one phase transition from delocalization of the qubit to quasi-localization was observed, here we will show two additional phases of partial localization appearing.

References:

[1] D. J. Egger and F. K. Wilhelm, Phys. Rev. Lett. 111, 163601 (2013)

Q 58.10 Thu 16:30 Empore Lichthof

Superballistic center-of-mass motion in one-dimensional attractive Bose gases: Decoherence-induced Gaussian random walks in velocity space — •Christoph Weiss[1], Simon Cornish[1], Simon Gardiner[1], and Heinz-Peter Breuer[2] — [1]Joint Quantum Centre (JQC) Durham–Newcastle, Department of Physics, Durham University, United Kingdom — [2]Physikalisches Institut, Univ. Freiburg, Germany

We show that the center-of-mass motion of ultracold attractively interacting bosons can become superballistic in the presence of decoherence, via single-, two- and/or three-body losses. In the limit of weak decoherence, we analytically solve the numerical model introduced in [1]. The analytical predictions allow us to identify experimentally accessible parameter regimes for which we predict superballistic motion of the center of mass. Ultracold attractive Bose gases form weakly bound molecules, quantum matter-wave bright solitons. Our computer-simulations combine ideas from classical field methods ("truncated Wigner") and piecewise deterministic stochastic processes. While the truncated Wigner approach to use an average over classical paths as a substitute for a quantum superposition often is an uncontrolled approximation, here it predicts the exact root-mean-square width when modeling an expanding Gaussian wave packet. In the superballistic regime, the leading-order of the motion can thus be modeled as a quantum superposition of classical Gaussian random walks in velocity space.

[1] C. Weiss et al., Phys. Rev. A 91, 063616 (2015).
[2] C. Weiss et al., arXiv:1510.05204

Q 58.11 Thu 16:30 Empore Lichthof

Resonance fluorescence spectrum of a laser-cooled atom trapped in a non-harmonic potential — •Ralf Betzholz and Marc Bienert — Theoretische Physik, Universität des Saarlandes, D-66123 Saarbrücken, Germany

Single trapped atoms open the possibility of realizing well controlled quantum interfaces. When the atom, trapped in a non-harmonic potential, is cooled by a laser the spectral sidebands of the emitted light allow to monitor the dynamics of the motional degrees of freedom and the readout of the thermal distribution. We evaluate the laser cooling and the spectrum of resonance fluorescence for two examplary trapping potentials: an infinite square well potential and the Morse potential.

Q 58.12 Thu 16:30 Empore Lichthof

Efficient coupling of a trapped moving atom to a single photon in free space — •Thorsten Haase, Nils Trautmann, and Gernot Alber — Institut für Angewandte Physik, Technische Universität Darmstadt

The efficiency of the coupling of a single trapped two-level-system to a single photon in free space is strongly affected by the two level system's center of mass motion, especially if no sub-Doppler cooling techniques are applied [1]. By squeezing the center of mass state, the coupling efficiency of the two level system to a single photon can be greatly enhanced. Squeezing can be induced by parametric amplification due to a time dependent modulation of a harmonic trapping potential which can be realized even in cases of a weak trapping potential. We investigate the dynamics of the center of mass motion in the modulated trapping potential by taking dissipative processes into account which are induced by Doppler cooling.

[1] M. Fischer, M. Bader, R. Maiwald, A. Golla, M. Sondermann, and G. Leuchs, Applied Physics B 117, 797 (2014).

Q 58.13 Thu 16:30 Empore Lichthof

Light-light interaction in strong plane-wave laser fields — Sebastian Meuren, •Sergey Bragin, Rashid Shaisultanov, Christoph H. Keitel, and Antonino Di Piazza — Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, D-69117 Heidelberg

While according to classical electrodynamics the superposition principle holds in vacuum, in quantum field theory light interacts with a background electromagnetic field via virtual charged particles. If the field is effectively of the order of the critical field of QED, also the transformation of a photon into a real electron-positron pair becomes sizable (nonlinear Breit-Wheeler process). These light-light interaction effects could be measurable at upcoming laser facilities like Vulcan 10P, ELI and XCELS [1]. Here, we present the momentum distribution of Breit-Wheeler electron-positron pairs in detail and introduce an intuitive semiclassical model which explains all qualitative features of the corresponding spectrum [2]. Also, we study the exact photon propagator inside a plane-wave laser field [3]. Due to light-light interaction the propagation of a photon through the background field is modified in a nontrivial way. By solving the Dyson-Schwinger equations we obtain a compact expression valid to one-loop order and discuss possible applications of our finding.

[1] A. Di Piazza et al., Rev. Mod. Phys. **84**, 1177–1228 (2012)
[2] S. Meuren, C. H. Keitel, and A. Di Piazza, arXiv:1503.03271 (2015)
[3] S. Bragin et al., in preparation.

Q 58.14 Thu 16:30 Empore Lichthof

Analytical tools for investigating strong-field QED processes in tightly focused laser fields — Antonino Di Piazza and •Alessandro Angioi — Max-Planck-Institut für Kernphysik,

Saupfercheckweg 1, D-69117 Heidelberg

The theoretical analysis of QED processes in intense laser fields has been limited to within the plane-wave approximation [1], even if the very high intensities considered in those analysis are, as of today, only reachable by focusing the laser energy almost to diffraction limit. Here we construct single-particle fermion states in the presence of a background electromagnetic field of general space-time structure within the WKB approximation [2]. Our main assumption is the realistic one that the initial energy of the electron is the largest dynamical energy scale in the problem. A substitution rule is found that allows these states to be obtained from the well-known Volkov wave functions in a plane-wave field [3]. Moreover, scalar and spinor propagators are constructed under the same approximations. The development of these tools opens in particular the possibility of investigating strong field QED processes in the presence of tightly focused strong fields analytically.

[1] A. Di Piazza et al., *Rev. Mod. Phys.* **84**, 1177 (2012).
[2] A. Di Piazza, *Phys. Rev. Lett.* **113**, 040402 (2014).
[3] A. Di Piazza, *Phys. Rev. A* **91**, 042118 (2015).

Q 58.15 Thu 16:30 Empore Lichthof

Many-body phases emerging from the competition between long-range and short-range potentials — •Rebecca Kraus[1], Katharina Rojan[1], Hessam Habibian[2,3], 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

We consider the Bose-Hubbard model for ultracold bosonic atoms confined by an optical lattice inside an optical resonator. The atoms interact with a cavity mode whose wavelength is incommensurate with the spatial periodicity of the confining potential, as considered in [1]. We consider a two-dimensional gas and identify the parameter tuning the strength of the long-range cavity mediated potential and the onsite interaction. In absence of the cavity, the second incommensurate potential is absent and the well-known Superfluid-Mott insulator transition is found. For small cavity fields, the cavity potential stabilizes glassy phases at sufficiently small kinetic energy [1]. We complete the diagram by analysing the situation, when the cavity potential is dominant over the onsite interaction and discuss the nature of the phases we identifiy.

[1] H.Habibian et al., Phys. Rev. Lett. 110, 075304 (2013)

Q 58.16 Thu 16:30 Empore Lichthof

Realizations of non-linear quantum maps in the one-atom maser model — •Felix Weber, Zsolt Bernád, and Gernot Alber — Institut für Angewandte Physik, Tenchnische Universität Darmstadt, D-64289 Darmstadt

We investigate the iterative behavior of a single mode cavity field which interacts repeatedly with two-level atoms. In our scenario two-level atoms are successively inserted into the cavity containing a superposition of Fock states and interact with this field. Subsequently, the atoms leaving the cavity are postselected. We study the behavior of the photonic state resulting from many iterations of this postselection process. For arbitrary initial conditions and interaction times the fixed points of this transformation and the state to which the field converges after many iterations are determined.

Q 58.17 Thu 16:30 Empore Lichthof

Towards Cavity QED with N-type atoms — •Karl Nicolas Tolazzi, Christoph Hamsen, Haytham Chibani, Tatjana Wilk, and Gerhard Rempe — Max Planck Institute of Quantum Optics, Hans-Kopfermann-Str. 1, 85748 Garching, Germany

The combination of electromagnetically induced transparency (EIT) and cavity QED leads to an interesting new regime with large light-light coupling [1]. This can be realized by a single atom with a lambda-type level scheme where one atomic transition (probe) is strongly coupled to an optical cavity. The second transition (control) in the lambda scheme can then be used to control the properties of the probe light field. Extending this scheme to an atom with a N-type level scheme where an additional transition (signal) is also strongly coupled to the cavity enables control of the EIT resonance [2,3]. This is due to the cavity-enhanced ac-Stark shift of the atomic levels by the signal light field. Thus even single photons in the signal field result in a detuning of the narrow EIT window which leads to considerable phase shifts in the probe beam [4]. This so called cross-phase modulation (XPM) can be understood as a strong effective Kerr nonlinearity which can be engineered on demand. We present first steps towards an experimental realization of this scheme with single ^{87}Rb atoms trapped inside a high finesse optical Fabry-Perot resonator of variable length.

[1] M. Mücke et al., Nature **465**,7299 (2010).
[2] A. Ímamoğlu et al., Physical Review Letters, **79**,8 (1997).
[3] S. Rebić et al., Journal of Optics B **1**,4 (1999).
[4] A. Feizpour et al., Nature Physics **11**,11 (2015).

Q 58.18 Thu 16:30 Empore Lichthof

Quantum dynamics in spatially resolved two-atom cavity-QED — •Matthias Körber, Andreas Neuzner, Olivier Morin, Stephan Ritter, and Gerhard Rempe — Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Str. 1, 85748 Garching

Embedding an optical emitter in a Fabry-Perot-type optical cavity has become a well-established technique to study the interaction of matter with a single mode of the light field. By extending this system to multiple atoms coupling to the same cavity mode, novel effects and degrees of freedom emerge compared to the single atom case: When an atom pair is driven with a laser transversal to the cavity axis, the difference position of the atoms defines the relative phase with which the atoms couple to the driving laser and the cavity mode. To achieve experimental control over this new degree of freedom, we pin two atoms to the sites of a two-dimensional optical lattice in the plane spanned by the cavity axis and the direction of the driving laser. The relative distance between the occupied lattice sites is determined via fluorescence imaging with single-site resolution.Thereby, the phase difference of the two atoms can be resolved. We show that the intensity and the correlation properties of the light scattered into the cavity strongly depend on this relative phase, and foresee further studies of fundamental aspects of light-matter interaction enabled by our experimental setting.

Q 58.19 Thu 16:30 Empore Lichthof

Strong optical nonlinearity induced by weakly interacting ions — •Robert Johne and Thomas Pohl — Max Planck Institute for the Physics of Complex Systems, Nöthnitzer Straße 38, 01187 Dresden, Germany

The generation of strong optical nonlinearities at smaller and smaller pump powers is a long-standing goal of technological and fundamental significance. The ultimate challenge is a single-photon nonlinearity, where a single light quantum is sufficient to drastically alter the system response for subsequent ones. Here we show that such a strong optical nonlinearity can be generated by weakly interacting ions placed in a cavity. In contrast to the conventional photon blockade based on the Jaynes-Cummings nonlinearity, the present system does not require ultrahigh quality cavities since the nonlinearity is induced by ion-ion interactions. We theoretically analyse in detail the system dynamics in dependence on various parameters and show that a strong nonlinear response is maintained although the ion-ion interaction strength is orders of magnitude smaller than all other parameters such as the cavity loss rate. The system holds great promise for advanced applications in quantum information processing e.g. single photon switches as well as for the deterministic generation of photon Fock states.

Q 58.20 Thu 16:30 Empore Lichthof

Long high finesse fiber Fabry-Pérot resonators — Konstantin Ott[1,2], Sébastien Garcia[1], Francesco Ferri[1], •Torben Pöpplau[1], Ralf Kohlhaas[1], Klemens Schüppert[3], Romain Long[1], and Jakob Reichel[1] — [1]Laboratoire Kastler Brossel, ENS/CNRS/UPMC, Paris (France) — [2]LNE-SYRTE, Observatoire de Paris/CNRS/UPMC, Paris (France) — [3]Institute for Experimental Physics, University Innsbruck, Austria

We present the realization of millimeter-long fiber coupled open Fabry-Pérot resonators with a finesse of 46.000. Deterioration of the finesse with increasing resonator length observed in previous experiments could be suppressed by advances in the CO2 laser-based fabrication process of the fiber micro mirrors. In this way, resonator lengths up to 1.4 mm could be realized, corresponding to a free spectral range of 107 GHz and linewidths of 2.2 MHz.

Fiber-based micro-cavities are of great use in experimental quantum information science, as they have many application benefits. The reduced apparatus size and direct fiber coupling lead to an increased stability. Beyond concave mirror structures, the novel multi-pulse laser fabrication technique further allows to enlarge the range of accessible structures, including asymmetric mirror profiles, convex shapes on fiber tips and on macroscopic fused silica substrates.

Q 58.21 Thu 16:30 Empore Lichthof

3D motional ground state cooling and collective scattering of two atoms inside a high-finesse cavity — •Natalie Thau, Wolfgang Alt, Tobias Macha, Lothar Ratschbacher, René Reimann, Seokchan Yoon, and Dieter Meschede — Institut für Angewandte Physik der Universität Bonn, Wegelerstr. 8, 53115 Bonn

Tight control and knowledge of the motional states of single atoms are a prerequisite for many cavity-QED experiments. In our system single cesium atoms coupled to a high finesse optical cavity are cooled close to the 3D motional ground state by means of resolved Raman sideband cooling. Two Raman beams are formed by a blue detuned dipole trap and a perpendicularly adjusted running wave driving Raman transitions between two hyperfine ground states. Thereby we strongly suppress motional carrier transitions along the dipole trap axis [1]. Efficient cooling along all three dimensions is implemented with a second pair of Raman beams using the intracavity dipole trap. Driving two atoms with a probe beam from the side we measure super- and subradient Rayleigh scattering into the cavity depending on the relative distance between the two atoms [2]. The information on the relative phase of the driving and cavity light fields at the atom positions and efficient pinning of the atoms in their 3D optical lattice due two Raman cooling are important for the implementation of two-atom entanglement schemes [3].

[1] R. Reimann *et al.*, New J. Phys. **16**, 113042 (2014)
[2] R. Reimann *et al.*, Phys. Rev. Lett. **114**, 023601 (2015)
[3] F. Reiter *et al.*, New J. Phys. **14**, 053022 (2012)

Q 58.22 Thu 16:30 Empore Lichthof

Fabrication and characterization of Fabry-Pérot microcavities — •Felix Glöckler, Andrea Kurz, Andreas Dietrich, Fedor Jelezko, and Alexander Kubanek — University Ulm, Institute for Quantum Optics, Germany

Starting with the question whether the excited-state lifetime of an atom can be modified, many experiments have been performed in order to engineer the properties of quantum emitters. The change of spontaneous emission is typically associated with Purcell*s prediction that the radiation of a dipolar transition can be accelerated with a cavity by the Purcell factor $F_P = \frac{3\lambda^3}{4\pi^2}\frac{Q}{V}$ which is mainly dependent on the quality factor Q and the Volume V of the cavity. Realizing high Purcell factors via the recipe high Q low V is non-trivial. Open Fabry-Pérot cavities are particularly attractive to achieve this goal since they are easily tunable and compatible with different kinds of emitters. In this work we will concentrate on achieving sizable F_P by optimizing the Q/V ratio.

Q 58.23 Thu 16:30 Empore Lichthof

Many-Body Dynamics Through Measurement and Feedback — •Jonas Lammers[1,2], Hendrik Weimer[1], and Klemens Hammerer[1,2] — [1]Institut für Theoretische Physik, Leibniz Universität Hannover — [2]Max-Planck-Institut für Gravitationsphysik (Albert-Einstein-Institut), Hannover

Time-continuous homodyne measurements and feedback allow for efficient quantum control of a broad range of systems, such as cavity and circuit QED, atomic ensembles, or optomechanics. Here we consider interferometric measurements on an array of such systems. We derive the corresponding feedback master equation, and apply it for the generation of many-particle entangled, stationary states (such as Bell, GHZ, and W states), and for the engineering of non-equilibrium dynamics of many-body systems (such as dissipative Ising models).

Q 58.24 Thu 16:30 Empore Lichthof

Ion-ion entanglement with large numerical aperture optics — •Daniel Higginbottom[1,2], Gabriel Araneda[2], Lukáš Slodička[2,3], Lukas Lachman[3], Radim Filip[3], Yves Colombe[2], and Rainer Blatt[2] — [1]ANU, Australia — [2]Universität Innsbruck, Österreich — [3]Palacký University, Czech Republic

We trap short strings of ions at the focus of large numerical aperture optics as a means of generating quantum optical fields and ion-ion entanglement. We generate single photon Fock states and demonstrate their purity by measuring violations of a non-Gaussian field witness [1]. We then entangle two trapped ions with a single-photon herald by indistinguishably coupling the ions to a single detection mode [2]. Parity measurements characterize the bipartite entanglement and we describe an additional entanglement signature measured by scattering a second photon from the entangled state. The collection efficiency of the lenses used in these experiments limits the single-photon source efficiency and the entanglement fidelity and generation rate. We present the fabrication and characterization of hemispheric mirrors for stronger atom-light coupling and outline how such a mirror may be used to enhance or suppress the spontaneous emission of an ion trapped at the mirror's centre of curvature [3].

[1] R. Filip, L. Mišta, Phys. Rev. Lett. 106, 200401 (2011). [2] L. Slodička, G. Hétet, N. Röck, P. Schindler, M. Hennrich, R. Blatt, Phys. Rev. Lett. 110, 083603 (2013). [3] G. Hétet, L. Slodička, A. Glätzle, M. Hennrich, R. Blatt, Phys. Rev. A 82, 63812 (2010).

Q 58.25 Thu 16:30 Empore Lichthof

Entanglement of Polarization and Orbital Angular Momentum — •Daniel Bhatti[1,3], Joachim von Zanthier[1,3], and Girish S. Agarwal[2] — [1]Institut für Optik, Information und Photonik, Universität Erlangen-Nürnberg, 91058 Erlangen, Germany — [2]Department of Physics, Oklahoma State University, Stillwater, OK, USA — [3]Erlangen Graduate School in Advanced Optical Technologies (SAOT), Universität Erlangen-Nürnberg, 91052 Erlangen, Germany

It is known that for identical particles entangled states can be constructed using different degrees of freedom, e.g., linear momentum and polarization. Recently it was shown that also orbital angular momentum (OAM), another degree of freedom of the radiation field, can be employed for entanglement generation [1]. We discuss the particular case of two photons with the same linear momentum but entangled in polarization and OAM degrees of freedom [2]. We show how to produce such entangled states and use the recently introduced concept of duality [3,4] to perform entanglement sorting. Here, the entangled character can be detected by studying either polarization variables or OAM variables using appropriate witnesses. In both cases identical information is obtained if the particles are indistinguishable. We also present generalizations to three- and four-photon entangled states.

[1] A. Mair, et al., Nature 412, 313 (2001).
[2] D. Bhatti, J. von Zanthier, G. S. Agarwal, Phys. Rev. A 91, 062303 (2015).
[3] S. Bose, D. Home, Phys. Rev. Lett. 110, 140404 (2013).
[4] J.-J. Ma, et al., New Journal of Physics 16, 083011 (2014).

Q 58.26 Thu 16:30 Empore Lichthof

Entanglement of an open quantum system with its environment — •Nina Megier[1], Ansgar Pernice[1], Franziska Peter[2], and Walter T. Strunz[1] — [1]TU Dresden — [2]Universität Potsdam

To investigate entanglement of an open quantum system with its environment the description using the reduced density matrix is not sufficient. By a linear coupling to the bath of harmonic oscillators the partial P-representation allows to efficiently determine the total state of system and environment. We use this approach in a Markov approximation. With the Peres-Horodecki separability criterion we study system - environment entanglement.

Q 58.27 Thu 16:30 Empore Lichthof

exact entanglement dynamics under the influence of a common structured environment using HOPS — •Richard Hartmann and Walter T. Strunz — Institut für Theoretische Physik, Technische Universität Dresden, D-01062 Dresden, Germany

Open quantum systems have to be considered as the general case when examining quantum mechanics experimentally or its technical applications. Therefore the computation of the so called reduced dynamics gains interest in many areas of physics, although no exact and efficient method has been developed yet. Especially when dealing with strong system-bath interactions the "hierarchy of pure states" (HOPS) [1] promises an interesting approach to estimate the exact non Markovian reduced dynamics.

Motivated by the vast progress in implementing qubits in solid state nano devices, we focus in this work on the entanglement dynamics of two non interacting qubits coupled to a common sub-ohmic bosonic bath. Questions such as entanglement decay and sudden death of entanglement as well as entanglement creation are addressed by comparing the exact numeric results gained using HOPS with approximative results employing the Redfield master equation and a second order week coupling expansion of the non Markovian quantum state diffusion equation [2].

[1] D. Süss, A. Eisfeld, and W.T. Strunz, Phys. Rev. Lett. 113, 150403 (2014).
[2] L. Diósi, N. Gisin, W.T. Strunz, Phys. Rev. A 58, 1699–1712

(1998).

Q 58.28 Thu 16:30 Empore Lichthof

Collisional decoherence of polar molecules — •Kai Walter, Benjamin A. Stickler, and Klaus Hornberger — Faculty of Physics, University of Duisburg-Essen, Germany

Collisions with background gases are an important source of environmental decoherence in interference experiments with molecular matter waves [1]. So far, the theoretical description of this effect is limited to the case of isotropic interactions between the colliding pair [2]. However, the large molecules envisioned for future experiments [3] are typically characterized by a permanent dipole moment, implying an orientation-dependent interaction. We present a theoretical description of the decoherence of polar molecules due to collisions with environmental gas atoms. The result is discussed by considering a concrete far-field setup.

[1] Hornberger et al., Phys. Rev. Lett. 90, 160401 (2003)
[2] Hornberger et al., Phys. Rev. A, 70, 053608 (2004)
[3] Arndt et al., Nat. Phys. 10, 271 (2014)

Q 58.29 Thu 16:30 Empore Lichthof

Towards a Lorentz-invariant quantum master equation — •Marduk Bolanos and Klaus Hornberger — Fakultät für Physik, Universität Duisburg-Essen

There is an ongoing effort to test the predictions of quantum theory in systems involving a large number of particles. The experiments performed in the last decade have motivated several measures of the macroscopic character of the systems under study. The empirical measure in [1] is based on a minimal modification to the von Neumann equation, that is invariant under *Galilean transformations* and induces the quantum-classical transition.

In this project we aim to develop an extension of the method presented in [1], that allows us to analyze on empirical grounds the macroscopic character of photonic experiments described by a *Lorentz-invariant* theory. As a starting point, in this work we develop a classical master equation with the required invariance property. This result will provide a useful reference when we consider the quantum-classical transition in a relativistic setting.

[1] Nimmrichter and Hornberger, PRL 110, 160403 (2013).

Q 58.30 Thu 16:30 Empore Lichthof

Attractor Spaces of Dissipatively Dephased Random Unitary Evolution and Quantum Darwinism — •Nenad Balaneskovic[1], Gernot Alber[1], and Jaroslav Novotny[2] — [1]Institut für Angewandte Physik, Technische Universität Darmstadt, D-64289 Darmstadt, Germany — [2]Department of Physics, FNSPE, Czech Technical University in Prague, 11519 Praha 1 - Stare Mesto, Czech Republic

We discuss characteristic properties of Quantum Darwinism (QD) [1] involving pure decoherence [4], dissipation and dephasing [3]. In particular, we reconstruct and derive the structure of the corresponding dissipatively dephased attractor spaces of our random unitary qubit-model of QD [2] and investigate whether QD appears with respect to evolution based on non-Controlled-NOT (non-CNOT) unitary operations. We identify those attractor space structures that allow the most efficient storage of classical information about a system into its environment. Furthermore, we conclude that CNOT-type unitary operations appear to be well suited copy-machines when it comes to efficiently store the information about a system's pointer basis into the environment. [1] W. H. Zurek, Nature Physics 5, 181-188 (2009). [2] Novotny, J., Alber, G., I Jex, I., J. Phys A 45, 485301 (2012). [3] V. Scarani et al., Phys. Rev. Lett. 88, 097905 (2002). [4] N. Balaneskovic, EPJD 69, 232 (2015).

Q 58.31 Thu 16:30 Empore Lichthof

Detecting the Berry curvature in photonic graphene — •Holger Fehske and Rafael L. Heinisch — Institut für Physik, Universität Greifswald, Greifswald, Germany

We propose a method for measuring the Berry curvature from the wave-packet dynamics in perturbed arrays of evanescently coupled optical waveguides with honeycomb lattice structure. To disentangle the effects of the Berry curvature and the energy dispersion we suggest a difference measurement by propagating the wave packet under the influence of a constant external force back and forth. In this way a non-vanishing Berry curvature is obtained for photonic graphene with small sublattice bias or strain, where the relative error between the exact Berry curvature and the one derived from the semiclassical dynamics is largely negligible. For the strained lattice we demonstrate the robustness of the Berry curvature texture over the Brillouin zone compared to the energy dispersion.

Q 58.32 Thu 16:30 Empore Lichthof

Symmetry transtion in a periodic parity-time-symmetric potential induced in an atomic sytem — •Lida Zhang and Jörg Evers — Max Planck Institute for Nuclear Physics, 69117 Heidelberg

We propose a feasible scheme to produce a periodic parity-time (PT) symmetric potential using standing-wave laser fields in an atomic system which combines two different physical processes, i.e., electromagnetically induced transparency and active Raman gain. The resulting band structure of the system shows completely real eigenvalues when the imaginary part of the potential is below a certain limit, corresponding an unbroken PT phase. However, as exceeding this limit, pairs of complex eigenvalues start to enter in the band edge, referring to a broken PT phase. The transition between unbroken and broken PT symmetry can be further characterized by an order parameter. Under two-level approximation, we obtain analytical expressions for the eigenvalues, with which we understand the emergence of complex eigenvalues in a deeper physical level. Moreover, we find a simple analytical solution for the order parameter, which agrees perfectly well with numerical results. Finally, additional nonlocal nonlinear effects is addressed by introducing Rydberg-Rydberg interactions. We find the symmetry transition can be either broken or recovered by the nonlocal nonlinear effects.

Q 58.33 Thu 16:30 Empore Lichthof

Lasing Without Inversion in Quecksilber bei 253,7 nm — Benjamin Rein, •Jochen Schmitt und Thomas Walther — TU Darmstadt, Institut für Angewandte Physik, AG Laser und Quantenoptik, Schlossgartenstr. 7, D-64289 Darmstadt

Mit herkömmlichen Lasersystemen werden Wellenlängen im ultravioletten Bereich im Dauerbetrieb in der Regel mittels Frequenzverdopplung bzw. -vervierfachung erreicht. Einen weiteren Ansatz, um in diesen Frequenzbereich vorzudringen, bietet Lasing Without Inversion (LWI), welches die Anregung atomarer Kohärenzen ausnutzt, um die Absorption des unteren Laserniveaus zu unterdrücken, also folglich ohne Besetzungsinversion funktionieren kann. Als Medium wird im gezeigten Experiment Quecksilber verwendet, welches durch die vorhandenen Niveaus Laserübergänge bei 253,7 nm und 185 nm ermöglicht. Für die Anregung der atomaren Kohärenzen werden Laser der Wellenlänge 435,8 nm und 546,1 nm benötigt, in dieser Konstellation kann LWI bei der Wellenlänge 253,7 nm realisiert werden. Der aktuelle Stand des Forschungsprojekts wird diskutiert.

Q 58.34 Thu 16:30 Empore Lichthof

Ein Titan:Saphir Lasersystem zur Erzeugung von ns-Pulsen bei 420 nm und 1995 nm — •Tobias Eggert[1], Vincenzo Talluto[1], Thomas Walther[1], Lukas Mader[1] und Thomas Blochowicz[2] — [1]Institut für Angewandte Physik, Technische Universität Darmstadt, Schlossgartenstr. 7, 64289 Darmstadt — [2]Institut für Festkörperphysik, Technische Universität Darmstadt, Hochschulstr. 8, 64289 Darmstadt

Wir stellen ein gepulstes Titan:Saphir Lasersystem bei 840 nm vor, das durch nichtlineare Frequenzkonversionsprozesse ns-Pulse bei 420 nm und 1995 nm erzeugt. Durch Injection-Seeding und einer kompakten Bauweise bietet das System sehr stabile und kurze Buildup Zeiten. Dies ermöglicht neben der Differenzfrequenzmischung des frequenzverdoppelten Titan:Saphir Pulses mit dem Pumppuls auch die Synchronisation mehrerer Lasersysteme.

Q 58.35 Thu 16:30 Empore Lichthof

Photon statistics of quantum-dot superluminescent diodes — •Franziska Friedrich and Reinhold Walser — Institut für Angewandte Physik, Darmstadt, Germany

Commercial devices for optical coherence tomography greatly benefit from the appealing features of broadband light emitting quantum-dot superluminescent diodes (QDSLDs), where light is generated in the regime of amplified spontaneous emission (ASE). But also from the fundamental point of view, these devices exhibit uncommon properties considering field and intensity correlations, $g^{(1)}(\tau)$ and $g^{(2)}(\tau)$: a reduction of $g^{(2)}(0)$ from 2 to 1.33 at $T = 190$ K was observed in the lab in 2011 [1]. The understanding of these hybrid coherent light states, which are simultaneously incoherent in $g^{(1)}(\tau)$ and coherent in $g^{(2)}(\tau)$, represents an interesting and challenging topic of research.

In a previous study [2], we assumed that the quantum state of the emitted diode light is well described by a multimode phase-randomized Gaussian (PRAG) state. Amongst sundry results, the experiment measured time resolved $g^{(2)}(\tau)$ in the fs time scale using modern fast two-photon detectors. It turned out that the assumption of PRAG states agrees with experimental findings. In the present contribution, we will discuss a model of the QDSLD and study the generation of the amplified spontaneous emission on a microscopic level [3].

[1] M. Blazek, W. Elsäßer, Phys. Rev. A **84**, 063840 (2011)
[2] S. Hartmann et al., New J. Phys. **17**, 043039 (2015)
[3] to be published

Q 58.36 Thu 16:30 Empore Lichthof

Potassium Spectroscopy on a Sounding Rocket — •Kai Lampmann[1], Ortwin Hellmig[5], Markus Krutzik[2], Achim Peters[2,3], André Wenzlawski[1], Patrick Windpassinger[1,5], and The KALEXUS Team[1,2,3,4] — [1]Johannes Gutenberg-Universität, Mainz — [2]Humboldt-Universität zu Berlin — [3]Ferdinand-Braun-Institut, Leibniz-Institut für Höchstfrequenztechnik, Berlin — [4]Leibniz Universität Hannover — [5]Universität Hamburg

We present the laser system of the sounding rocket experiment KALEXUS. This mission is scheduled to be launched in spring 2016 and should demonstrate the fully autonomous operation of a system for laser frequency stabilization, which is required e.g. 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 options to handle possible system failures.

The spectroscopy module for absolute frequency stabilization to the potassium D2 line consists of special monolithic Zerodur components for guiding and overlapping the beams. A fiber based splitting module connects the different functional units of the system and provides a beat note detection for offset frequency stabilization. We show ground based characterization measurements of the spectroscopy system and tests for space qualification.

The KALEXUS project is led by the Humboldt-Universität zu Berlin and 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 58.37 Thu 16:30 Empore Lichthof

Laser system technology for rubidium atom interferometry aboard sounding rockets — •Vladimir Schkolnik[1], Markus Krutzik[1], Achim Peters[1,2], The MAIUS Team[1,2,3,4,5], and The FOKUS Team[1,2,3,4] — [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 are one of the key elements in modern precision experiments such as atom interferometers and atomic clocks. Future space missions including quantum interferometry based gravity mapping, 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 diode laser systems optimized for precision measurement applications with ultra-cold atoms aboard sounding rockets. Design, assembly and qualification of the laser system for the MAIUS mission, an atom interferometer with degenerate ^{87}Rb scheduled for launch 2016 is discussed.

All key technologies have already been successfully tested on a separate sounding rocket mission in 2015 by performing precision Doppler free spectroscopy in space on the TEXUS 51 mission. The payload and the experimental results are presented.

This work is supported by the German Space Agency DLR with funds provided by the Federal Ministry for Economic Affairs and Energy under grant numbers DLR 50WM 1237-1240, and 1345.

Q 58.38 Thu 16:30 Empore Lichthof

Automated experiment control and laser frequency stabilization of the KALEXUS experiment on a sounding rocket. — •Aline Dinkelaker[1], Andrew Kenyon[1], Max Schiemangk[1], Vladimir Schkolnik[1], Markus Krutzik[1], Achim Peters[1,2], and The KALEXUS Team[1,2,3,4,5] — [1]Institut für Physik, Humboldt-Universität zu Berlin — [2]FBH Berlin — [3]JGU Mainz — [4]LU Hannover — [5]Menlo Systems GmbH

To demonstrate the functionality of a laser system for atomic physics experiments in space, the KALEXUS experiment tests the performance of two frequency stabilized micro-integrated extended cavity diode lasers (ECDLs) on a sounding rocket for the first time. Most challenging is the sensitivity of ECDLs to vibrational and thermal effects as locking parameters can change throughout launch and flight, while real-time communication to adjust these parameters is not possible in our mission. Therefore we developed automated control software with a state machine to regulate the experiment during its sequence and perform absorption spectroscopy and different functional tests, including tests of fallback options and redundancy equipment. The experiment is autonomous from first switch-on and requires no manual control. We present the structure of the experimental control, focusing on the implementation of several layers of auto-detection for autonomous frequency stabilization in the changing environment of a sounding rocket.

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 58.39 Thu 16:30 Empore Lichthof

Noncollinear optical parametric oscillators for Raman Spectroscopy — •Luise Beichert[1], Yuliya Khanukaeva[1], and Uwe Morgner[1,2,3] — [1]Institute of Quantum Optics, Leibniz Universität Hannover, Welfengarten 1, 30167 Hannover, Germany — [2]Centre for Quantum Engineering and Space-Time Research (QUEST), Welfengarten 1, 30167 Hannover, Germany — [3]Laser Zentrum Hannover (LZH), Hollerithallee 8, 30419 Hannover, Germany

Meanwhile microplastics can be detected at an increasing rate in our oceans as well as in our drinking water. We present new light sources with a high bandwith and high output power for detecting these particles via simulated Raman scattering.

Noncollinear optical parametric oscillators (NOPOs) provide a good scalability in terms of power, repetition rate and pulse energy. The instantaneous broadband frequency conversion combined with the special phase matching geometry in the nonlinear crystal enables a fast tunability of the spectrum without readjustment.

We show the concept of a multi-colour NOPO for the Raman spectroscopy. Using the frequency-doubled radiation of an infrared pumplaser will lead to an IR-NOPO, tunable from 650 to 950 nm. With help of the third harmonic the spectrum will be shifted to the visible spectral regime. Introducing a second focus with an additional sum frequency process in the VIS-NOPO will even generate UV-radiation about 350 nm.

Q 58.40 Thu 16:30 Empore Lichthof

Two-color spectroscopy for laser stabilization to the ytterbium 1S0-3P1 intercombination line — •Christian Halter, Bastian Pollkeneser, Kapilan Paramasivam, Bastian Schepers, Tobias Franzen, Gregor Mura, and Axel Görlitz — Institut für Experimentalphysik, HHU Düsseldorf, 40225 Düsseldorf

We present a scheme for frequency stabilization of multiple lasers that are resonant to transitions and originating from a common ground state. For the detection of weaker transitions we are harnessing the high signal to noise ratio provided by a strong transition. Doppler reduced spectroscopy is performed on an atomic beam by detecting the fluorescence of a strong dipole allowed transition. Individual error signals for this transition as well as additional weaker transitions are recovered from the strong fluorescence signal using lock-in techniques. We demonstrate the application to strong 1S0-1P1 transition and the 1S0-3P1 intercombination line of ytterbium in the context of MOT.

Q 58.41 Thu 16:30 Empore Lichthof

Electromagnetic wave propagation in time-dependent Hermitian and non-Hermitian structures — •Armen Hayrapetyan[1], Jörg Götte[2], Sandra Klevansky[3], Stephan Fritzsche[4], Karen Grigoryan[5], and Rubik Petrosyan[5] — [1]Max-Planck-Institut für Physik komplexer Systeme, Dresden, Germany — [2]School of Physics and Astronomy, University of Glasgow, U.K. — [3]Institut für Theoretische Physik, Universität Heidelberg, Germany — [4]Helmholtz-Institut Jena, Germany — [5]Yerevan State University, Armenia

We study the impact of a spatially homogeneous yet non-stationary dielectric permittivity on the dynamical and spectral properties of light. We focus on two distinct scenarios in which time-dependent dielectric structures experience either Hermitian or non-Hermitian change. In the Hermitian case, a smoothly time-varying modification of the medium is considered in order to demonstrate the possibility of amplification and attenuation of waves associated with the decrease and increase of the permittivity. In the non-Hermitian case, using a complex-valued permittivity with parity-time symmetry, modulations of light amplification and attenuation are shown correspondingly linked to the well-defined regions of gain and loss. While real-valued permittivities give rise to either the conversion or the time-dependent modulation of the frequency, the parity-time symmetric permittivity, beyond some threshold, leads to the splitting of extrema in the frequency modulation and to a reduction of the modulation period. Our results may pave the way towards controllable light-matter interaction in time-varying structures.

Q 58.42 Thu 16:30 Empore Lichthof

Rydberg excitons in artificially grown cuprous oxide — •Moritz Fischer — 4th Physics Institute and Research Center SCoPE, Stuttgart, Germany

We investigate the yellow exciton series in an artificially grown crystal of cuprous oxide (chemical formula Cu2O) at low temperatures (1.9 K). The yellow green light (close to 571 nm) is generated by a combination of an external cavity diode laser and second-harmonic generation in a waveguide of lithium niobate. To our knowledge it is the first time that yellow excitons are observed in an artificially grown crystal of cuprous oxide. We achieved excitons with principal quantum numbers from n=4 to n=9. From the transmission spectrum we calculated the band gap to 2.172 04 eV of cuprous oxide and the Rydberg energy of the yellow excitons to 94.75 meV. The current limitation is the phonon-assisted absorption in lower excitonic states. We further investigate the opportunities of fiber-based measurement techniques in reflection in order to reach lower temperatures (50 mK) and overcome the critical issue of the sample thickness.

Q 58.43 Thu 16:30 Empore Lichthof

Edge diffraction of optical-vortex beams formed by means of a "fork" hologram — Aleksey Chernykh[1], Aleksandr Bekshaev[2], and •Anna Khoroshun[1] — [1]East Ukrainian National University, Severodonetsk, Ukraine — [2]I.I. Mechnikov National University, Odessa, Ukraine

We present experimental and numerical studies of a transverse profile for a beam obtained by the screen-edge diffraction of optical-vortex (OV) Kummer beams with different topological charges generated by means of a "fork" hologram. Our main results concern the behavior of secondary OVs formed in the diffracted beam due to splitting of the incident multi-charged OV into a set of single-charged ones. When the screen edge moves across the incident beam, OVs in every cross section of the diffracted beam describe complicated spiral-like trajectories which distinctly manifest the screw-like nature and the energy circulation in the OV beam. The trajectories contain fine structure details that reflect the nature and peculiar spatial configuration of the diffracting beam. For the Kummer beams' diffraction, the trajectories contain self-crossings and regions of "backward" rotation (loops). In the case of Laguerre-Gaussian beams, the trajectories are smoother. At certain conditions, positions of separate OVs as well as their mutual configuration (a singular skeleton of the diffracted beam) demonstrate high sensitivity to the screen edge dislocation with respect to the incident beam axis. This effect can be used for remote measurements of small displacements and deformations.

Q 58.44 Thu 16:30 Empore Lichthof

Determination of the relative emitter phases in an external-cavity diode laser array — •Mario Niebuhr and Axel Heuer — Institut für Physik und Astronomie, Universität Potsdam, 14476 Potsdam-Golm

Laser diodes (LD) with simultaneous high output power and good beam quality (BQ) are still a matter of ongoing research. One Ansatz which could enable LDs in corresponding applications is the coherent combination of multiple low power, good BQ emitters [1]. The emitters unfortunately tend to de-phase at high pump/output powers and the array loses coherence even when exposed to external seed or feedback.

We intend to investigate the cause of de-phasing by adapting a spatial light modulator based measurement method [2] to determine the relative phase difference between all emitters in an LD array. Measurements were done with an exemplary 9 emitter array radiating at 980nm and forced into coupled operation using an external cavity. Our method allowed for an accurate determination of the preset supermode phase relations as well as a convincing reconstruction of the emitted far field power distribution. Ideas will be presented on how to obtain an understanding of the possible de-phasing mechanisms.

[1] Fan et al, IEEE J. Sel. Top. Quantum Electron., 11, 567 (2005)
[2] Partanen et al., Fringe 2013. Springer Berlin Heidelberg, 879 (2014)

Q 58.45 Thu 16:30 Empore Lichthof

Quantum-inspired sensing of trapped particle kinematics — •Stefan Berg-Johansen[1,2], Martin Neugebauer[1,2], Peter Banzer[1,2,3], Andrea Aiello[1,2], Christoph Marquardt[1,2], and Gerd Leuchs[1,2,3] — [1]Max Planck Institute for the Science of Light, Guenther-Scharowsky-Str. 1/Bldg. 24, D-91058 Erlangen, Germany — [2]Institute of Optics, Information and Photonics, University of Erlangen-Nuremberg, Staudtstr. 7/B2, D-91058 Erlangen, Germany — [3]Department of Physics, University of Ottawa, 25 Templeton, Ottawa, Ontario, K1N 6N5 Canada

Recently, it was demonstrated that the inseparable mode structure of radially polarized beams of light can be used for kinematic sensing with gigahertz temporal bandwidth [1]. The technique relies on the intrinsic correlations existing between the transverse spatial and polarisation degrees of freedom of vector beams, having a mathematical structure similar to that of entangled quantum systems [2]. The high temporal resolution made possible by the method becomes particularly valuable when investigating phenomena occurring at comparatively short length scales, such as the Brownian motion of a microparticle.

Here, we report on progress in applying the new method to measurements on microparticles suspended in liquid and trapped by an optical tweezer.

[1] S. Berg-Johansen, F. Töppel *et al.*, Optica **2**(10), 864 (2015).
[2] R. J. C. Spreeuw, Phys. Rev. A **63**, 062302 (2001).

Q 58.46 Thu 16:30 Empore Lichthof

Diode laser pumped molecular lasers — •Bernd Wellegehausen[1] and Walter Luhs[2] — [1]Institut für Quantenoptik, Leibniz Universität Hannover, Welfengarten 1, 30167 Hannover, Germany — [2]2Photonic Engineering Office, Herbert-Hellmann Allee 57, 79189 Bad Krozingen, Germany

In the past, lasers with diatomic molecules as Na_2, Te_2, Se_2 and I_2 have been realized by optical pumping with argon and krypton ion lasers. Available powerful blue emitting laser diodes now open new possibilities for the generation of compact, low cost molecular laser systems. We report on first operation of lasers with Na_2 and Te_2 molecules on lines in the range of 535 nm to 636 nm, pumped by standard diode lasers at 461 nm and 445 nm. Investigations on the spectral narrowing of the diode lasers and features of the molecular lasers will be presented and discussed.

Q 58.47 Thu 16:30 Empore Lichthof

Zerodur-based optical systems for precision measurements in space — •André Wenzlawski[1], Moritz Mihm[1], Kai Lampmann[1], Ortwin Hellmig[2], Klaus Sengstock[2], Patrick Windpassinger[1], and the MAIUS Team[1,2,3,4,5,6] — [1]Johannes Gutenberg-Universität Mainz — [2]ILP, Universität Hamburg — [3]Institut für Physik, HU-Berlin — [4]IQO, Leibniz Universität Hannover — [5]ZARM, Universität Bremen — [6]FBH, Berlin

Stable and robust optical systems are a key technology for high precision experiments such as atom interferometers or atomic clocks. Future space missions which allow for key improvements in these fields additionally require a high degree of thermal and mechanical robustness for the individual components.

To fulfill these requirements we developed a number of optical systems based on the glass ceramic Zerodur, a material which excels in having a very low coefficient of thermal expansion (CTE) over a very broad temperature range.

We present different fiber-coupled modules whose functionalities range from spectroscopy of Rubidium or Potassium to intensity control and pulse shaping for the MAIUS-experiments realizing a BEC-based atom interferometer.

MAIUS is part of the QUANTUS project, which is supported by the German Space Agency DLR with funds provided by the Federal Ministry of Economics and Technology (BMWi) under grant numbers DLR 50 WM 1131 - 1137 and DLR 50 WP 1431 - 1435.

Q 58.48 Thu 16:30 Empore Lichthof

Temperature and frequency stabilisation in a cryogenic confocal microscope for single-site experiments — •Jan M. Binder, Lachlan J. Rogers, and Fedor Jelezko — Institute for Quantum Optics and IQST, Ulm University, Albert-Einstein-Allee 11, D-89081 Ulm, Germany

During our experiments on single-site crystal defects at liquid helium temperatures we have noticed that the spatial stability of our cryogenic confocal microscope is influenced significantly by the temperature of the surrounding laboratory. To a lesser extent this also applies to the frequency stability of the associated laser system.

We present a solution to the temperature stability problem of in the form of a cost-effective high current PID controller and thermoelectric temperature regulation.

We also show an approach to laser stabilisation combining multiple feedback signals of different inherent accuracy and sampling rates with the goal of enabling multi-hour measurements of fluorescence signals at low excitation power.

Q 58.49 Thu 16:30 Empore Lichthof

Field test of a Brillouin-LIDAR for temperature profiles of the ocean — •Sonja Friman[1], David Rupp[1], Andreas Rudolf[1], Charles Trees[2], and Thomas Walther[1] — [1]TU Darmstadt, Institut für Angewandte Physik, 64289 Darmstadt — [2]CMRE, 19136 La Spezia, Italy

In our group, a Brillouin-LIDAR for the measurement of temperature profiles of the ocean up to 100 m depths is being developed. It is meant to work as a flexible alternative to contact-based techniques. The temperature information is deduced from the Brillouin backscatter, which shows a temperature dependent spectral shift with respect to the incident laser frequency.

The LIDAR consists of a pulsed fiber amplifier as the beam source and an atomic edge filter as the detector. After frequency doubling, the ytterbium-doped fiber amplifier emits 10 ns pulses with a repetition rate of 1 kHz and a pulse energy of 0.5 mJ. The emission wavelength of 543.3 nm is set by the rubidium-based components of the setup: the absorption filter, which eliminates the elastic scattering from the signal, and the rubidium edge filter (ESFADOF).

The setup has successfully been tested under laboratory conditions, resulting in a temperature accuracy of up to 0.07°C and a depth resolution of 1 m. Recently, a field test was conducted in the Mediterranean.

The setup, its functionality and the preliminary results from the field test are presented.

Q 58.50 Thu 16:30 Empore Lichthof

Femtosecond pulse shaping of Laguerre-Gaussian laser pulses — •Tom Bolze and Patrick Nuernberger — Physikalische Chemie II, Ruhr-Universität Bochum, Universitätsstraße 150, 44801 Bochum

The temporal shaping of femtosecond laser pulses is widely used and well explored. A number of schemes have been demonstrated to achieve fast, stable and precise shaping of incident laser pulses. However the Hermite-Gaussian HG_{00} mode is almost exclusively used.
We present our results for shaping femtosecond Laguerre-Gaussian (LG) laser pulses with a pulse shaper. We employ a 128-pixel LCD in the common $4f$ geometry of a pulse shaper, a spiral phase plate (SPP) is used to transform the HG_{00} mode into the LG_{01} mode. Upon changing the spectral phase of the pulse we investigate the variations in the temporal shape of the pulse using a FROG-device and the spatial shape using a CCD-camera. The Orbital Angular Momentum (OAM) of the shaped pulse is determined in dependence on the applied spectral phase, hence we investigate whether complex spectral phases distort the spatial beam profile of femtosecond LG beams.

Q 58.51 Thu 16:30 Empore Lichthof

Design and implementation of a Kerr lens mode-locked air operated high-power thin disk oscillator — •José Ricardo Andrade, Bernhard Kreipe, and Uwe Morgner — Leibniz Universität Hannover, Institute for Quantum Optics, Welfengarten 1, 30167 Hannover, Germany

In this work we present some theoretical considerations and experimental evidence of how to design and operate a Kerr lens mode-locked thin disk laser in the high power regime (hundreds of Watt) in ambient air. This technology enables scaling down the size of high-power systems with the added benefit of not needing to reduce the repetition rate. In contrast to high-power thin disk lasers mode-locked by semiconductor saturable absorber mirrors, operation in air is feasible and the gain-bandwidth of the gain material is more properly exploited, making this type of systems better contenders for up-scaling.

Q 58.52 Thu 16:30 Empore Lichthof

Generation of sub 10 fs UV pulses with MHz repetition rate — •Sven Kleinert[1], Ayhan Tajalli[1], Bernhard Kreipe[1], Yuliya Khanukaeva[1], Tamas Nagy[1,3], and Uwe Morgner[1,2] — [1]Institut für Quantenoptik, Leibniz Universität Hannover, 30167 Hannover — [2]Laserzentrum Hannover e.V., 30419 Hannover — [3]Laser-Laboratorium Göttingen e.V., 37077 Göttingen

Energetic ultrashort UV pulses at high repetition rates are essential for wide fields of applications e.g. nonlinear imaging and ultrafast spectroscopy. A well-established technique for generation of such pulses is optical parametric amplification (OPA). However, the lack of proper nonlinear media as well as pump and seed sources make them difficult for UV pulse generation. One possible solution to this problem is a frequency conversion of these sources. Here, we present a broadband OPA in the visible region with a repetition rate of 1MHz which is used for generation of UV pulses with duration of sub 10fs via frequency doubling process. The driving laser source for this experiment is an Ytterbium-doped rod-type-fiber amplifier system delivering 600fs IR pulses with pulse energy of 50μJ. This source is used for generation of pump and seed for the OPA via third harmonic and supercontinuum generation processes in BBO and YAG crystals respectively. This very compact setup supports the generation of sub 9fs pulses in the visible range with pulse energy of more than 700nJ. The generation of sub 10fs UV pulses with pulse energy of more than 40nJ at 1MHz repetition rate is then guaranteed via second harmonic generation of the output.

Q 58.53 Thu 16:30 Empore Lichthof

Sub two-cycle optical pulse compression from Ti:sapphire oscillators — •Philip Dienstbier[1], Takuya Higuchi[1], John Travers[2], Francesco Tani[2], Michael Frosz[2], Philip St. J. Russell[2], and Peter Hommelhoff[1,2] — [1]Department Physik, Friedrich-Alexander-Universität Erlangen-Nürnberg (FAU), Staudtstrasse 1, 91058 Erlangen — [2]Max Planck Institute for the Science of Light, Günther-Scharowsky-Str. 1, Erlangen, Germany

Ultrashort pulsed lasers with a duration of a single oscillation of the electric field are an ideal tool to investigate the sub-cycle dynamics of electrons under an intense field [1]. Recent observation of rescattering physics at a nanotip with the aid of optical field enhancement suggests that such a strong-field sub-cycle regime can be reached with much lower pulse energy ($<$ 1 nJ) [2]. However, for such small pulse energy, difficulty in spectral broadening involving nonlinear optics hindered generation of sub two-cycle pulses. Here, we discuss how to broaden the spectrum of Ti:sapphire oscillator output by a customized solid core photonic crystal fiber and compress it back to its shortest pulse duration.

[1] M. T. Hassan *et al.*, Rev. Sci. Instrum. **83**, 111301 (2012).
[2] M. Krüger *et al.*, Nature **475**, 78 (2011).

Q 58.54 Thu 16:30 Empore Lichthof

Nanostructured laser-driven dielectric structures for electron focusing — •Alexander Tafel, Joshua McNeur, Martin Kozák, Ang Li, Norbert Schönenberger, and Peter Hommelhoff — Friedrich-Alexander-Universität

By combining the strong fields of ultrashort laser pulses and the large damage thresholds of dielectrics, dielectric laser accelerators (DLAs) hold great potential to reduce the size and cost of existant accelerators dramatically. Acceleration and deflection have already been demonstrated in several proof of principle experiments in a single stage [1,2,3]. To extend the interaction between electrons and the laser-induced fields, however, focusing elements must be introduced to counteract the divergence of the electron beam. Here, we present two candidates for this role: dielectric laser quadrupole structures - a setup of two 2D gratings - which work analogously to radio frequency quadrupoles and single-grating based electron lenses. The former can be used for strong focusing and simultaneous acceleration, microbunching and/or guiding of the beam. The latter have already shown to be effective electron focusing elements with focal distances on the order of 100 microns [4].

[1] J. Breuer and P. Hommelhoff, Phys. Rev. Lett. 111, 134803 (2013).
[2] E. A. Peralta et al. Nature 503, 91-94 (2013).
[3] M. Kozak, J. McNeur et al., submitted
[4] J, McNeur, M. Kozak et al., submitted

Q 58.55 Thu 16:30 Empore Lichthof

Nanoscale vacuum-tube electronic devices triggered by few-cycle laser pulses — •Constanze Sturm, Takuya Higuchi, Peyman Yousefi, Christian Heide, Kristof Kremer, and Peter Hommelhoff — Department Physik, Friedrich-Alexander-Universität Erlangen-Nürnberg (FAU), Staudtstrasse 1, 91058 Erlangen

Electron pulses from a sharp metal nanotip triggered by ultrashort laser pulses via multiphoton and above-threshold photoemission are extremely confined both in space and time. Employing such short-pulsed electrons as charge carriers in electronic devices may drastically improve their operation speed. As a first step, we demonstrate a nanoscale diode device triggered by few-cycle laser pulses [1]. While focusing the laser on two tips facing each other and separated by a few hundreds of nanometers, we exploit the dependence of the near-field optical enhancement on the tip radius. This dependence results in a photoemission yield that is larger for the sharper tip compared to the blunter one. As a consequence the laser-triggered current between two tips exhibits a rectifying behavior. For a systematic variation of the tip radii and a reliable control of the distance between the tips, we lithographically fabricated tips on top of a substrate. The current status of the experiments will be presented.

[1] T. Higuchi et al., Appl. Phys. Lett., 106, 051109 (2015).

Q 58.56 Thu 16:30 Empore Lichthof

A scanning tunneling microscope joined with few-cycle laser pulses — •Michal Hamkalo, Takuya Higuchi, M. Alexander Schneider, and Peter Hommelhoff — Department Physik, Friedrich-Alexander-Universität Erlangen-Nürnberg(FAU), 91058 Erlangen

Sharp metal tips are not only essential to perform scanning tunneling microscopy (STM), but also extremely interesting from the point of view of strong field physics as the apex of such a tip exhibits a large optical field enhancement. Due to this feature it is possible to achieve electric fields of the order of 1 V/Å and to enter the light-field-induced tunneling photoemission regime. Electrons resulting from this process rescatter at a distance of a few nanometers from tip surface [1]. When the tip apex is approached to another surface within such a distance, electrons are expected to tunnel in between the tip and the surface within a subcycle of the oscillating field. A tip-to-tip interface is an attracting playground for seeking such optical-field driven tunneling over a gap, but the mechanical instability of the previous setup hindered to reach this tunneling regime [2]. In this study, a STM-based setup with optical access was built and used to investigate tip-to-tip and tip-to-surface interfaces illuminated with few-cycle laser pulses.

1. M. Krüger, M. Schenk and P. Hommelhoff, Nature 475, 78 (2011).
2. T. Higuchi et al., Appl. Phys. Lett. 106, 051109 (2015).

Q 58.57 Thu 16:30 Empore Lichthof

Attosecond gating and streaking of free electrons via interaction with laser-induced optical fields — •Norbert Schönenberger, Martin Kozak, Joshua McNeur, and Peter Hommelhoff — Department Physik, Friedrich-Alexander-Universität Erlangen-Nürnberg (FAU), Staudtstr. 1, 91058 Erlangen

The recent successful demonstrations of dielectric laser acceleration have opened up the possibility of more advanced experiments and setups [1,2]. The experimental results presented here demonstrate optical gating and streaking of 28 keV free electrons with a precision of 1.3 fs [3]. This is achieved via the linear interaction of the light's electric field with the energy and transverse momentum of an electron beam near a dielectric grating. Furthermore, we discuss the potential applications of the demonstrated gating and streaking. The optical gating demonstrated here can be used for a wide range of ultrafast electron diffraction experiments that require sub-fs free electron probes. Moreover, a dielectric-laser based streak camera based off of this scheme could allow for temporal characterization of electron bunches with 10 attosecond precision. [1] J. Breuer, and P. Hommelhoff, Phys. Rev. Lett. 111, 134803 (2013). [2] E. A. Peralta, et al. Nature 503, 91-94 (2013). [3] M. Kozak, J. McNeur et al., submitted.

Q 58.58 Thu 16:30 Empore Lichthof

A Miniaturized Electron Source Based on Dielectric Laser Accelerator Operation at Higher Spatial Harmonics and a Nanotip Photoemitter — •Ang Li, Joshua McNeur, Martin Kozak, Dominik Ehberger, and Peter Hommelhoff — Department Physik, Friedrich-Alexander-Universität Erlangen-Nürnberg (FAU), Staudtstr. 1, 91058 Erlangen

Dielectric Laser Acceleration, a novel accelerator concept based on micron-scale dielectric grating structures driven by the high peak field of short laser pulses, can exceed the performance of RF-based accelerators. Recent experimental progress on dielectric laser acceleration of electrons with energies below 10 keV via interaction with high spatial harmonics of a DLA is discussed. Further, laser-triggered coherent electron emission from tungsten nanotips is discussed in the context of a novel DLA-based miniaturized electron gun[1]. The photoemitted low-emittance electron bunches suggests incorporation with sub-relativistic dielectric laser accelerators (DLAs). On tapered silicon grating structures, experimental results show an acceleration gradient (energy gain/interaction length) already analogous to the electron injectors in rf-based accelerators. The combination of the nanotip emitter with sub-relativistic DLAs to construct a mm-scale electron injector capable of producing arbitrary energies will be discussed.

[1] J. McNeur, D. Ehberger et al., J. Phys. B, accepted

Q 58.59 Thu 16:30 Empore Lichthof

Nano-structured chips for dielectric laser accelerators and laser triggered electron emission — •Peyman Yousefi, Joshua McNeur, Martin Kozak, and Peter Hommelhoff — Department Physik, Friedrich-Alexander-Universität Erlangen-Nürnberg (FAU), Staudtstr. 1, 91058 Erlangen, Germany

Laser-driven dielectric accelerators (DLAs) are based on the synchronicity of laser-induced electromagnetic fields and charged particles traversing nano-structured chips. Proof of principle experiments have shown efficient acceleration with energy gradients already exceeding those of RF accelerators [1,2]. To improve upon these gradients, new dielectric structures composed of varying materials must be built. Different techniques can be utilized to fabricate such structures depending on the material properties and the desired geometries. Electron beam lithography with spatial resolution of 2-5 nm enables us to pattern such structures down to 50 nm feature size. Depending on the geometry of the desired structure we use either reactive ion etching tool enhanced by inductive coupled plasma or deep reactive ion etching tool to etch different substrates (Si, SiO2, SiC, Al2O3 etc.). Furthermore, we report on recent results of the fabrication of an on chip electron source appropriate for integration with DLAs. An apex radius of about 30 nm and a cathode to anode gap of around 30 nm were achieved using focused ion beam (FIB) on a thin film of gold on a fused silica substrate. [1] J. Breuer, and P. Hommelhoff, Phys. Rev. Lett. 111, 134803 (2013). [2] E. A. Peralta, et al. Nature 503, 91-94 (2013).

Q 58.60 Thu 16:30 Empore Lichthof

Experimental study of photoelectronic angular distributions using velocity map imaging: Intensity and CEP effects — •Eike Lübking[1], Thomas Gaumnitz[2], Christoph Vorndamme[1], Tamas Nagy[1], Torsten Hartmann[1], Uwe Morgner[1], Thorsten Uphues[2], and Milutin Kovacev[1] — [1]Institut für Quantenoptik, Leibniz Universität Hannover, Welfengarten 1, 30167 Hannover, Germany — [2]Center for Free-Electron Laser Science, Universität Hamburg, Luruper Chausee 149, 22761 Hamburg, Germany

A Velocity Map Imaging Spectrometer (VMIS) was used to study the angular and energy distributions of photoelectrons created in the ultrashort-pulse ionization of xenon and argon.

The intensity dependence of these distributions can be utilised to gain insight into the diverse participating processes, e.g. channel switching and resonant and non-resonant ionization.

By using a CEP-stabilized laser source generating few-cycle pulses, we were also able to study the influence of the carrier-envelope phase (CEP) on the photoelectronic angular distributions.

Q 58.61 Thu 16:30 Empore Lichthof

Selective etching of fs-laser structured crystalline YAG — •Kore Hasse[1,2], Christian Kränkel[1,2], and Thomas Calmano[1,2] — [1]Institut für Laser-Physik, Universität Hamburg — [2]The Hamburg Centre for Ultrafast Imaging, Universität Hamburg

The etching rate of fs-laser structured dielectric materials is increased within the modified region by order of magnitude. This enables the fabrication of narrow hollow structures with dimensions comparable to those of the fs-inscribed structures of a few micrometers. In future this may allow modifying active laser and amplifier materials and influence their transversal mode profile or suppress amplified spontaneous emission (ASE).

Here we report on preliminary investigations on selective etching of fs-laser structured wedges in undoped YAG-samples. We present etching rates of unmodified YAG and those of YAG crystals modified with different fs-laser pulse parameters. Furthermore, we compare roughness and scattering losses of fs-laser assisted etched surfaces and surfaces resulting from direct laser ablation.

Q 58.62 Thu 16:30 Empore Lichthof

Few-cycle pulse conversion by soliton implosion — •Jan-Hendrik Oelmann[1], Ihar Babushkin[1,2], Ayhan Tajalli[1], Hakan Sayinc[3], Uwe Morgner[1,3,4], Günter Steinmeyer[2], and Ayhan Demircan[1,4] — [1]Institute of Quantum Optics, Leibniz University

Hannover, Welfengarten 1, 30167 Hannover — [2]Max-Born-Institute (MBI), Max-Born-Str. 2a, 12489 Berlin, Germany — [3]Laser Zentrum Hannover e. V., Hollerithallee 8, 30419 Hannover, Germany — [4]Hannover Centre for Optical Technologies, Nienburger Str. 17, 30167 Hannover, Germany

We predict a new regime of coherent supercontinuum generation in photonic-crystal fibers based on few-cycle higher order soliton dynamics. Instead of using the standard soliton fission process, we exploit dramatic shock formation dynamics of a higher-order soliton, which completely converts the input solitonic radiation to different wavelength regions in the normal dispersion regime. This enables the transfer of energy to coherent radiation in the visible as well as the ultraviolet spectral range. The scheme is simple, very effective and completely deterministic, which suggests the possibility to compress the pulses down to the sub-cycle level and thus hold a new way to directly generate attosecond pulses well outside the vacuum ultraviolet. We present numerical simulations for commercially available fibers with realistic pulse parameters and present preliminary experimental results, supporting the theoretical prediction.

Q 58.63 Thu 16:30 Empore Lichthof

Exploiting optical event horizon concept in microstructured optical fibers to manipulate higher older soliton trajectories — •Ayhan Tajalli[1], Alexander Pape[1], Ihar Babushkin[1,2], Günter Steinmeyer[2], Uwe Morgner[1,3], and Ayhan Demircan[1,4] — [1]Institut Für Quantenoptik, Leibniz Universität Hannover, 30167 Hannover — [2]Max-Born-Institut (MBI), 12489 Berlin — [3]Laserzentrum Hannover e.V., 30419 Hannover — [4]Hannover Centre for Optical Technologies, 30167 Hannover

Supercontinuum generation in photonic crystal fibers has been of great interest to optical scientists since its discovery. More interestingly, it has recently revealed some unexpected analogy to different areas of physics including event horizon and rogue waves. The concept of event horizon in supercontinuum generation relies on enhanced interaction between a signal and a phase velocity matched control pulse which results in mutual frequency change of both pulses. Here, we experimentally demonstrate the possibility of accelerating or decelerating of ejected fundamental solitons in the supercontinuum generation. By choosing an appropriate choice of the initial conditions including fiber parameters, wavelength, energy and temporal delay of the weaker control pulse we verify the strong all optical controlling possibility of this interaction

Q 58.64 Thu 16:30 Empore Lichthof

Floquet-engineering topological and spin-dependent bands with ultracold fermions — •Gregor Jotzu, Michael Messer, Frederik Görg, Daniel Greif, Remi Desbuquois, Martin Lebrat, Thomas Uehlinger, and Tilman Esslinger — Institute for Quantum Electronics, ETH Zurich, 8093 Zurich, Switzerland

Periodically driven quantum systems, when observed on time-scales longer than one modulation period, can be described by effective Floquet Hamiltonians that show qualitatively new features. Using a magnetic field gradient, we apply an oscillating force to ultracold fermions in an optical lattice. The resulting effective energy bands then become spin dependent, allowing for a tunable ratio of the effective mass for each internal state, also giving access to the regime where one spin is completely localized whilst the other remains itinerant.

In a honeycomb lattice, circular modulation leads to the appearance of complex next-nearest neighbour tunnelling. This corresponds to a staggered magnetic flux in the lattice, allowing for the realisation of Haldane's model of a topological Chern insulator. When spin dependence is included, time-reversal symmetry can be restored giving rise to the Kane-Mele model.

A crucial question is whether Floquet engineering can be extended to interacting systems, and how the resulting Hamiltonians are modified. In particular, we study how heating in the system depends on the modulation and interaction parameters and identify regimes where it becomes negligible.

Q 58.65 Thu 16:30 Empore Lichthof

Connecting strongly correlated superfluids by a quantum point contact — •Martin Lebrat[1], Samuel Häusler[1], Dominik Husmann[1], Sebastian Krinner[1], Jean-Philippe Brantut[1], Shun Uchino[2], Thierry Giamarchi[3], and Tilman Esslinger[1] — [1]Institute for Quantum Electronics, ETH Zürich, 8093 Zürich, Switzerland — [2]Center for Emergent Matter Science, RIKEN, Saitama 351-0198, Japan — [3]Department of Quantum Matter Physics, University of Geneva, 1211 Geneva, Switzerland

We study strongly interacting Fermi gases connected by a tunable, ballistic constriction and measure a non-linear current-bias relation, reminescent of superconducting weak links. We prepare an elongated cloud of ultracold ^{6}Li at unitarity by tuning its scattering length close to a Feshbach resonance. The cloud is then pinched off at its center using repulsive laser beams, effectively splitting it into two macroscopic reservoirs connected by a one-dimensional constriction, a quantum point contact (QPC).

By imposing an atom number imbalance between the two clouds and observing the dynamics of particle flow, we analyse the current-bias characteristics of our system and find nonlinear behaviour indicating superfluid behaviour. The results agree quantitatively with a biased superfluid point contact model treated with the Keldysh formalism, suggesting that the supercurrent originates from multiple Andreev reflections. We study how the current-bias characteristics depend on the density in the QPC and finite temperature.

Q 58.66 Thu 16:30 Empore Lichthof

Anti-ferromagnetic correlations with ultracold fermions on optical lattices — Daniel Greif[1,2], Gregor Jotzu[1], Michael Messer[1], Frederik Görg[1], •Rémi Desbuquois[1], and Tilman Esslinger[1] — [1]Institute for Quantum Electronics, ETH Zurich, 8093 Zurich, Switzerland — [2]Department of Physics, Harvard University, Cambridge, Massachusetts 02138, USA

The observation of anti-ferromagnetic spin correlations of ultracold fermions in optical lattices is an important milestone towards an experimental study of the Hubbard model. In this model many questions on the low-temperature phase diagram still remain open, both for simple cubic and square configurations, as well as for more complex lattice geometries. Additionally, for creating an equilibrated low-temperature state and a successful implementation of advanced cooling schemes based on entropy redistribution, an understanding of the formation time for spin correlations is of paramount importance.

In our experiment we load a two-component, repulsively interacting fermionic quantum gas into an optical lattice of tunable geometry. For very low temperatures we observe anti-ferromagnetic correlations on neighbouring sites in many different lattice geometries. Furthermore, we investigate the characteristic formation time of spin correlations in optical lattices by changing the lattice geometry on variable timescales.

Q 58.67 Thu 16:30 Empore Lichthof

Realization of the ionic Hubbard model with ultracold fermions on optical lattices — Michael Messer[1], •Rémi Desbuquois[1], Thomas Uehlinger[1], Gregor Jotzu[1], Frederik Görg[1], Sebastian Huber[2], Daniel Greif[1,3], and Tilman Esslinger[1] — [1]Institute for Quantum Electronics, ETH Zurich, 8093 Zurich, Switzerland — [2]Institute for Theoretical Physics, ETH Zurich, 8093 Zurich, Switzerland — [3]Department of Physics, Harvard University, Cambridge, Massachusetts 02138, USA

Ultracold atoms in optical lattices constitute a tool of choice to realize the Fermi-Hubbard model. Previous experiment showed that, by increasing the on-site repulsive interactions, a gap opens in the excitation spectrum and the system becomes progressively a Mott insulator. A more simple band insulator appears in half filled lattices when a staggered energy offset is introduced. There, the ground state possesses charge density-wave ordering. The competition of both phenomena constitute the ionic Hubbard model, which we experimentally realize by loading a two-component interacting Fermi gas into an optical lattice with a staggered energy offset on alternating sites. The underlying density order of the ground state is revealed through the correlations in the noise of the measured momentum distribution. For a large energy offset, we observe a charge density-wave ordering, which is suppressed as the on-site interactions are increased. To further elucidate the nature of the ground state, we measure the double occupancy of lattice sites and show a gapped charge excitation spectrum for a wide range of parameters.

Q 58.68 Thu 16:30 Empore Lichthof

The quasi-particle residue in the crossover from few to many particles — •Michael Dehabe, Andrea Bergschneider, Simon Murmann, Vincent M. Klinkhamer, Jan-Hendrik Becher, Gerhard Zürn, and Selim Jochim — Physikalisches Institut, Universität Heidelberg, Heidelberg, Germany

In one dimension, the ground-state wave function of an impurity particle interacting with a Fermi sea is orthogonal to the ground-state wave function in the non-interacting case. Hence, the squared overlap of these two wave functions, which is known as quasi-particle residue, is zero.

By measuring the quasi-particle residue of a single impurity atom and an increasing number of majority atoms we want to study the emergence of orthogonality in the system. We deterministically prepare these few-fermion systems in a cigar-shaped optical dipole trap in their motional ground state. This system can be considered as quasi one-dimensional, if the atom number is smaller than the aspect ratio of the trap. For each specific number of majority particles, we determine the quasi-particle residue by flipping the spin of the impurity particle using a resonant RF pulse and measuring the Rabi frequency.

In our current experimental setup, the aspect ratio limits the number of majority particles to values smaller than five. We will present our latest results on increasing the aspect ratio of the trap while keeping full control over the quantum state of the few-atom system. This will allow us to study the quasi-particle residue in the crossover to the many-body limit.

Q 58.69 Thu 16:30 Empore Lichthof

Deterministic Preparation of Few-Fermion Systems in Actively Stabilized Potential Wells — •Vincent M. Klinkhamer, Jan-Hendrik Becher, Andrea Bergschneider, Michael Dehabe, Simon Murmann, Gerhard Zürn, and Selim Jochim — Physikalisches Institut der Universität Heidelberg, Im Neuenheimer Feld 226, 69120 Heidelberg, Germany

In our experiment we control the total wave function of several interacting ^{6}Li atoms trapped in multiple coupled dimple traps. In our previous experiments with a double-well potential, we were able to prepare two-particle eigenstates by adiabatically tuning the depth of the two wells with an acousto-optic deflector (AOD). However, the ramps of the optical potential had to be optimized experimentally and we also observed drifts on the scale of the superexchange energy J^2/U. This inhibited our progress towards larger systems.

Here we present the first results of our new stabilization setup for the optical potential. It can directly produce potential landscapes and ramps by monitoring the potential on a camera in real time. At the same time, it provides a relative stability of 5×10^{-4}. This will allow us to conveniently create potentials with multiple sites. We are going to deterministically prepare, e.g., one-dimensional Hubbard chains and four-site plaquettes. Thanks to the control over the preparation, it will also be possible to introduce various amounts of doping into our system.

Q 58.70 Thu 16:30 Empore Lichthof

Spin Resolved Imaging of an Ultracold Fermi Gas in a 2D Optical Lattice — •Ralf Klemt, Luca Bayha, Puneet Murthy, Mathias Neidig, Martin Ries, Gerhard Zürn, and Selim Jochim — Physikalisches Institut, Universität Heidelberg, Germany

We report on the current status of our experiment investigating an ultracold, two-component ^{6}Li Fermi gas in the BEC-BCS crossover, which is trapped in a 2D optical lattice. By using a matterwave focusing technique, we measure the momentum distribution which allows access to spatial coherence information. We realize both a transition from the normal to the superfluid phase and from the superfluid to an insulating phase by tuning the temperature and the lattice depth, respectively. For the insulating phase a loss of first-order correlations and phase coherence is expected. Probing the type of this insulating phase as well as observing spin-ordering requires to measure second-order, i.e. atom-noise, correlations.

Therefore a spin resolved two-state imaging has been implemented, which allows for recording both hyperfine states of the 6Li gas within a single experimental cycle. This was achieved combining fast current modulation of a diode laser and the interline transfer mode of a CCD camera. Hence the density profile of both spin components can be measured within 100μs, keeping the distortion between the images at a minimum. With this tool at hand the spatial atom-noise correlations between the different spin components can be obtained in addition to single spin correlations.

Q 58.71 Thu 16:30 Empore Lichthof

Strongly interacting ultracold quantum gases of fermionic Ytterbium-173 — •Luis Riegger[1,2], Diogo Rio Fernandes[1,2], Moritz Höfer[1,2], Christian Hofrichter[1,2], Francesco Scazza[1,2], Immanuel Bloch[1,2], and Simon Fölling[1,2] — [1]Ludwig-Maximilians-Universität, Schellingstraße 4, 80799 München, Germany — [2]Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Straße 1, 85748 Garching, Germany

Degenerate ensembles of ytterbium and alkaline-earth atoms allow novel many-body systems to be implemented due to their extended SU(N)-symmetry and the existence of a metastable internal "clock" state, introducing a yet unexplored orbital degree of freedom. Motivated by the possibility of simulating two-orbitals physics with cold atoms, we investigate the coupling of the clock state to external degrees of freedom via state-dependent potentials. In addition we characterize strongly interacting SU(N)-symmetric Fermi gases of ^{173}Yb in the 3D lattice by probing the equation of state in the trap.

Q 58.72 Thu 16:30 Empore Lichthof

Probing Many-Body Localizition With a Gas of Ultracold Fermions in Optical Lattices — •Pranjal Bordia[1,2], Henrik Lüschen[1,2], Sean Hodgman[1,2,3], Michael Schreiber[1,2], Immanuel Bloch[1,2], and Ulrich Schneider[1,2,4] — [1]Fakultät für Physik, Ludwig-Maximillians-Universität München, Schellingstr. 4, 80799 Munich, Germany — [2]Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Str. 1, 85748 Garching, Germany — [3]Research School of Physics and Engineering, Australian National University, Canberra ACT 0200, Australia — [4]Cavendish Laboratory, University of Cambridge, J. J. Thomson Avenue, Cambridge CB3 0HE, United Kingdom

Many Body Localization (MBL) offers a generic alternative to thermalization in isolated quantum systems in which a many-body system fails to act as its own heat bath, even at finite energy densities. However, it is crucial for such a phenomenon that the system undergoes strictly closed system dynamics.

We present our recent work on probing MBL with ultra-cold fermions loaded in optical lattices by preparing an out of equilibrium change density wave and monitoring the relaxation dynamics. We will describe two experiments where we studied the effects of taking the system controllably away from the ideal isolated 1D case and describe how it influences the many-body state.

Q 58.73 Thu 16:30 Empore Lichthof

Microscopic Observations in Degenerate Fermionic Lattice Gases — •MARTIN BOLL[1], TIMON HILKER[1], AHMED OMRAN[1], KATHARINA KLEINLEIN[1], GUILLAUME SALOMON[1], IMMANUEL BLOCH[1,2], and CHRISTIAN GROSS[1] — [1]Max-Planck Institute of Quantum Optics — [2]Faculty of Physics, LMU Munich

Ultracold atoms in optical lattices provide a powerful platform for the controlled study of quantum many-body physics. We present here the first studies of a Fermi gas with a new generation quantum gas microscope, which allows to observe the full atom number statistics on every site. The common problem of light induced losses is avoided by an additional small scale "pinning lattice" for Raman sideband cooling during the imaging.

We report the local observation of Pauli's exclusion principle in a spin-polarized degenerate gas of ^{6}Li fermions in an optical lattice. In the band insulating regime, we measure a strong local suppression of particle number fluctuations and we extract a local entropy as low as 0.3 k_B per atom. In addition we present our progress studying the metal to Mott-insulating transition. Our work opens an avenue for studying local density and even magnetic correlations in fermionic quantum matter both in and out of equilibrium.

Q 58.74 Thu 16:30 Empore Lichthof

Goldstone mode in the quench dynamics of an ultracold BCS Fermi gas — •Peter Kettmann[1], Simon Hannibal[1], Mihail Croitoru[2], Vollrath Martin Axt[3], and Tilmann Kuhn[1] — [1]Institute of Solid State Theory, University of Münster — [2]Condensed Matter Theory, University of Antwerp — [3]Theoretical Physics III, University of Bayreuth

Ultracold Fermi gases are a convenient system to probe and study the properties of phases like the BEC and the BCS phase and the crossover in between those regimes. In particular, ultracold Fermi gases can be used as a test bed to study the two fundamental dynamical modes –the Higgs and the Goldstone mode– which result from spontaneous symmetry breaking in these phases.

We investigate the Goldstone mode in the dynamics of a cigar-shaped ultracold ^{6}Li gas after an interaction quench on the BCS side of the BCS-BEC crossover. To this end, we numerically solve Heisenberg's equations of motion for the Bogoliubov single-particle excitations in the framework of the Bogoliubov-de Gennes formalism. In doing so, we find that the single-particle occupations oscillate in time with one dominant low-frequency component. We identify this frequency as the frequency of the Goldstone mode of the BCS gap [1]. Furthermore, we investigate the Goldstone mode over a wide range of parameters and show that the size-dependent superfluid resonances [2] have a strong impact on this mode.

[1] Kettmann et al., arXiv preprint arXiv:1511.04239 (2015)
[2] Shanenko et al., PRA 86, 033612 (2012)

Q 58.75 Thu 16:30 Empore Lichthof

Confinement-induced effects on the Higgs mode of an ultracold Fermi gas after a quench — •Simon Hannibal[1], Peter Kettmann[1], Mihail Croitoru[2], Vollrath Martin Axt[3], and Tilmann Kuhn[1] — [1]Institute of Solid State Theory, University of Münster — [2]Condensed Matter Theory, University of Antwerp — [3]Theoretical Physics III, University of Bayreuth

Ultracold Fermi gases in optical traps provide a unique system to study the many body physics of systems composed of fermionic constituents. Both, the BEC and the BCS superfluid state are observed in these systems. Furthermore, the transition between these two states is well controllable by means of a Feshbach resonance, which allows one to tune the interaction strength over a wide range from negative to positive scattering lengths.

We employ an inhomogeneous BCS mean field theory and calculate the dynamics of the BCS gap of a confined ultracold Fermi gas after a quantum quench, i.e., a sudden change of the coupling constant. Due to the spontaneously broken U(1) symmetry in the superfluid phase two fundamental modes of the BCS gap evolve, i.e., the amplitude (Higgs) and phase (Goldstone) mode. Here we focus on the Higgs mode on the BCS side of the BCS-BEC crossover regime.

We find damped collective amplitude oscillations of the gap breaking down after a certain time. Depending on the quench parameters we investigate the damping and fragmentation of the Higgs mode exploiting a set of linearized equations of motions. Thereby, we illuminate the impact of the confinement on the dynamics of a BCS-BEC system.

Q 58.76 Thu 16:30 Empore Lichthof

Towards a 2D gas of Fermions in an optical lattice — •Thomas Paintner, Daniel Hoffmann, Stefan Häussler, Stephan Maier, Wladimir Schoch, Wolfgang Limmer, and Johannes Hecker Denschlag — Institut für Quantenmaterie, Universität Ulm, Ulm, Deutschland

Fermions in optical lattices increasingly gain attention, because they represent a promising model system to simulate interesting solid-state phenomena. We are currently setting up a quantum gas microscope experiment for an ultracold 2D fermionic Lithium gas. We plan to expose the 2D gas to a honeycomb type optical potential which is projected on the atomic layer by a high resolution objective. The atoms inside this lattice will be cooled down using the Raman sideband cooling technique. In the future we want to implement single atom detection with single site resolution. We present a progress report of our set up.

Q 58.77 Thu 16:30 Empore Lichthof

Towards single site single atom imaging of ^{6}Li atoms in an optical honeycomb potential — •Stefan Häussler, Thomas Paintner, Daniel Hoffmann, Wladimir Schoch, Wolfgang Limmer, and Johannes Hecker Denschlag — Institute for Quantum Matter, Ulm University, Albert-Einstein-Allee 45, 89081, Ulm, Germany

We are setting up a fermionic quantum gas experiment with ultracold ^{6}Li atoms in the quasi two-dimensional regime. The gas will be structured with an optical honeycomb potential, projected with a high resolution objective. Such a system should enable us to investigate interesting phases of the fermionic ensemble at different lattice parameters and interaction strengths. For detection we will implement single site fluorescence imaging of the particles.
Since the fluorescence detection leads to heating of the atoms due to light scattering, thermal hopping of the atoms in the lattice can occur. To suppress this effect during detection, we will make use of a Raman sideband cooling technique as shown in [1].
The Raman cooling scheme, which is used to reduce the thermal energy of the particles in the honeycomb potential and simultaneously delivers the spontaneously emitted photons for the fluorescence imaging is presented here, as well as the required laser setup, which includes a 10 GHz offset frequency locking scheme and a digital feedback control based on a wavelengthmeter. Using this locking scheme first experimental results on Raman spectroscopy are presented.

[1] M. Greiner: Phys. Rev. Let. 114, Nr. 213002 (2015)

Q 58.78 Thu 16:30 Empore Lichthof

Setup of a new lithium quantum gas microscope — •Michael Hagemann, Andreas Kerkmann, Yann Kiefer, Niels Rohweder, Benno Rem, Christof Weitenberg, and Klaus Sengstock — Institut für Laserphysik, Universität Hamburg, Luruper Chaussee 149, 22761 Hamburg, Germany

We are setting up a new quantum gas machine for the preparation of small degenerate samples of 6Li atoms with single atom resolved detection and manipulation. We use a compact 2D-MOT/3D-MOT setup and plan to create the degenerate gases in a glass cell at the position of the 3D-MOT. After a lambda-enhanced grey molasses phase, we want to directly load into a crossed optical dipole trap at 1070 nm. We will present the current status of the experiment including the setup of the laser system and its locking scheme, the design of the magnetic field coils, and the interferometer for testing the deformation of the glass cell.

Q 58.79 Thu 16:30 Empore Lichthof

Probing Open Quantum Systems Using Ultracold Yb in Optical Lattices — •André Kochanke, Bastian Hundt, Thomas Ponath, Benjamin Abeln, Anna Skottke, Lukas Heinze, Klaus Sengstock, and Christoph Becker — Zentrum für Optische Quantentechnologien, Universität Hamburg, Luruper Chaussee 149, 22761 Hamburg

Open quantum systems are an important and active field of research and highly relevant for applications like quantum information processing as well as fundamental questions in many body systems. Ultracold Ytterbium (Yb) gases are an ideal candidate to simulate these phenomena. With its unique atomic structure, Yb offers meta-stable, excited states which are subject to very strong two-body losses. These loss channels are the origin for many quantum effects like entanglement or the "Quantum-Zeno" effect. Here we present our latest results concerning these model systems. In a 3-D optical lattice we selectively prepare single-spin or spin-mixture gases of ^{173}Yb. Starting with a Band- or Mott-Insulator, we collectively populate the meta-stable $^3P_0$ state by means of Rapid-Adiabatic-Passage to measure and characterize the losses for different lattice configurations and extract information about the underlying time evolution. Further, we present details of our experimental setup used to perform these measurements. This work is supported by the DFG within the SFB 925 and the Marie Curie Initial Training Network QTea, financed by the FP7 of the European Commission (contract-no. MCITN-317485).

Q 58.80 Thu 16:30 Empore Lichthof

Using Raman sideband cooling to build Fermi-Hubbard systems atom by atom — •Phillip Wieburg, Christian Darsow-Fromm, Lennart Sobirey, Thomas Lompe, and Henning Moritz — Institut für Laserphysik, Universität Hamburg, Luruper Chaussee 149, 22761 Hamburg, Germany

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

Here we present the design of this new experiment, which is going to be able to cool a gas of 40K to quantum degeneracy as well as to directly lasercool single atoms into optical microtraps. To achieve loading of single atoms with high fidelity, we can exploit light-assisted collisions as described in [1]. The cooling of the atoms will be performed using a Raman-sideband cooling techniques similar to the one described in [2]. In order to image and to manipulate the atoms with high spatial resolution, our setup will be equipped with a novel achromatic imaging system located inside the vacuum chamber.

[1] T. Grünzweig et al., Nature Physics 6 951 (2010).
[2] A.M. Kaufman et al., Physical Review X 2 041014 (2012).

Q 58.81 Thu 16:30 Empore Lichthof

Modulation spectroscopy of ultracold fermions in optical superlattices — •Karla Loida, Jean-Sébastien Bernier, and Corinna Kollath — HISKP, Universität Bonn, Nussallee 14-16,

53115 Bonn

We study the excitation spectrum of the ionic Hubbard model. The ionic Hubbard model consists of three terms: a nearest-neighbor tunneling, an onsite interaction and an alternating energy offset between even and odd sites. It was originally introduced for the description of condensed matter systems, e.g. mixed stacked organic compounds, and can be cleanly realized by ultracold fermionic atoms confined to an optical superlattice. Its phase diagram in one dimension has attracted considerable theoretical interest. In the limits of predominating energy offset or onsite interaction strength, the ground state is a band insulator or Mott insulator, respectively. In between a narrow so-called bond-ordered wave phase has been predicted which spontaneously breaks site-inversion symmetry. The excitation spectrum of the ionic Hubbard model has attracted much less attention so far. We exert a time-periodic modulation of the superlattice amplitude and study the exact time-dependence within the time-dependent density matrix renormalization group method. Our study is motivated by the possibilities of experimental probing in cold atomic gas experiments where our choice of perturbation corresponds to lattice amplitude modulation spectroscopy of superlattice geometry.

Q 58.82 Thu 16:30 Empore Lichthof

A Laser System for Cooling of Yb Atoms — •Benjamin Nagler, Tobias Eul, Carsten Lippe, Benjamin Gänger, Jan Phieler, Thomas Pinnel, Christina Weirich, and Artur Widera — Technische Universität Kaiserslautern, Fachbereich Physik und Landesforschungszentrum Optimas, Erwin-Schrödinger-Str. 46, 67663 Kaiserslautern, Germany

Quantum gases have proven useful tools to gain insight into fundamental phenomena of quantum physics. The working horse for preparation of these systems is laser cooling of dilute atomic gases. Here we report on the current state of preparing an ultracold gas of Ytterbium atoms, focusing on the laser system developed. This features blue light generation by second harmonic generation several hundreds of MHz detuned from the atomic transition for operating a Zeeman slower, stabilized onto an atomic resonance. We will show key features of the laser system and present measurements of the system characteristics.

Q 58.83 Thu 16:30 Empore Lichthof

Fermionic many-body states under the microscope — •Daniel Greif[1], Maxwell F. Parsons[1], Anton Mazurenko[1], Christie S. Chiu[1], Sebastian Blatt[1,2], Florian Huber[1], Geoffrey Ji[1], and Markus Greiner[1] — [1]Department of Physics, Harvard University, Cambridge, Massachusetts 02138, USA — [2]Max-Planck-Institut für Quantenoptik, 85748 Garching, Germany

We report on site-resolved imaging of various fermionic many-body states of ultracold Li-6 in a square optical lattice, including metallic, Mott-insulating and band-insulating phases. The insulating states show a suppression in the single-site occupation variance and a spatially constant filling fraction. A comparison to theory shows that the system is in global thermal equilibrium with fitted global entropies of $1.0\,k_{\rm B}$. We also report on our most recent progress towards probing magnetically ordered quantum states with the quantum gas microscope.

Q 58.84 Thu 16:30 Empore Lichthof

Cloud Shape of Dipolar Fermi Gases — •Vladimir Veljić[1], Antun Balaž[1], Aristeu R. P. Lima[2], and Axel Pelster[3] — [1]Scientific Computing Laboratory, Institute of Physics Belgrade, University of Belgrade, Serbia — [2]UNILAB, Brazil — [3]Physics Department and Research Center OPTIMAS, Technical UIniversity of Kaiserslautern, Germany

In a recent time-of-flight (TOF) expansion experiment for ultracold polarized fermionic erbium atoms it was shown that the Fermi surface has an ellipsoidal shape [1]. It was also observed that the Fermi surface follows a rotation of the dipoles, which is induced by changing the direction of the external magnetic field, keeping the major axis always parallel to the direction of maximal attraction of the dipole-dipole interaction. Here we present a theory for determining the cloud shape in both real and momentum space by extending the work of Ref. [2], where the magnetic field is oriented along one of the harmonic trap axes, to an arbitrary orientation of the magnetic field. In order to analyze the cloud shape within TOF dynamics, we solve analytically the corresponding Boltzmann-Vlasov equation by using a suitable rescaling of the equilibrium distribution [3]. The resulting ordinary differential equations of motion for the scaling parameters are solved numerically in the collisionless regime at zero temperature and turn out to agree with the observations in the Innsbruck experiment [1].

[1] K. Aikawa, et al., Science **345**, 1484 (2014).
[2] F. Wächtler, A. R. P. Lima, and A. Pelster, `arXiv:1311.5100`.
[3] P. Pedri, et al., Phys. Rev. A **68**, 043608 (2003).

Q 58.85 Thu 16:30 Empore Lichthof

Development of a digital phase lock for optical lattices — •Dominik Vogel, Nick Fläschner, Matthias Tarnowski, Benno Rem, Christof Weitenberg, and Klaus Sengstock — Universität Hamburg, Germany

Non-separable optical lattices feature new physics as for example Dirac cones and Berry phases in the case of the hexagonal lattice, which is formed by three interfering beams. Usually, the lattice beams pass through optical fibers for optimal beam profiles and therefore pick up independent phases, which translate the lattice potential and thus couple acoustic noise to the ensemble of ultra cold atoms, leading to heating.

In this poster, we present a digital phase locked loop that fixes those phases by controlling the laser frequencies via AOMs. The loop features a 800 kS/s bipolar analog to digital converter, a real time processor and a DDS frequency source. Our setup enables a total feeback signal delay under 2 micro seconds, while providing the high linewidth quality of a DDS-source, which is superior to conventional analog phase locks. In closed loop, we achieve a significant reduction of the phase noise, which is expected to increase the atomic life time in the optical lattice and thus provides access to new temperature regimes.

Q 58.86 Thu 16:30 Empore Lichthof

Towards quantum gas microscopy of ultracold potassium atoms — •Tobias Wintermantel, Emil Pavlov, Alda Arias, Stephan Helmrich, and Shannon Whitlock — Physikalisches Institut, Universität Heidelberg, Im Neuenheimer Feld 226, 69120 Heidelberg

Ultracold quantum gases in optical lattices are a versatile model system for engineering many-body quantum systems. Additionally, the advent of single-atom-resolution imaging techniques enables one to extract an unprecedented degree of information on the spatial correlations.

We are constructing a new experiment featuring fermionic or bosonic potassium atoms in optical lattices with reduced dimensional confinement. A special aspect will be the ability to introduce and control long-range interactions between the atoms via optical dressing of Rydberg states. A high-resolution imaging setup for probing these quantum gases, mainly consisting of an in-vacuum high-NA objective lens and a high quantum efficiency EMCCD camera, is currently under construction. The expected imaging quality depends, on the one hand, on the constraints of the imaging system (numerical aperture, aberrations and detector noise) and on the other hand, on physical constraints such as the number of photons which can be scattered before the atoms are heated and lost out of the microtraps. We present our progress in quantifying these effects for imaging Rydberg-dressed quantum fluids.

Q 58.87 Thu 16:30 Empore Lichthof

Density dependent synthetic magnetism — •Sebastian Greschner[1], Daniel Huerga[2], Gaoyong Sun[1], Dario Poletti[3], and Luis Santos[1] — [1]Institut für Theoretische Physik, Leibniz Universität Hannover, Germany — [2]Institut fur Theoretische Physik III, Stuttgart — [3]Engineering Product Development, Singapore University of Technology and Design

Raman-assisted hopping can allow for the creation of density-dependent synthetic magnetism for ultracold neutral gases in optical lattices. In 1D the density-dependent Peierls phases can be mapped the anyon Hubbard model which exhibits a rich groundstate physics including unconventional two-component superfluid phases and statistically driven phase transitions [1]. In 2D square lattices we observe a non-trivial interplay between density modulations and effective magnetic fluxes as well as intriguing dynamical properties [2].

[1] S. Greschner and L. Santos, Phys. Rev. Lett. 115, 053002, 2015
[2] S. Greschner, D. Huerga, G. Sun, D. Poletti, and L. Santos, Phys. Rev. B 92, 115120, 2015

Q 58.88 Thu 16:30 Empore Lichthof

Heteronuclear Spin-Changing-Collisions in Li-Na mixtures — •Arno Trautmann, Fabián Olivares, Marcell Gall, Fred Jendrzejewski, and Markus K. Oberthaler — Kirchhoff-Institut für Physik, Im Neuenheimer Feld 227, 69120 Heidelberg

Homonuclear Spin-Changing-Collisions are a well-known tool in ultracold atomic samples to study entanglement, magnetism and the rich field of both bosonic and fermionic spinor physics. Spin-Changing-Collisions of atoms with different species can extend these tools even further to investigate collective effects of spinor mixtures. We present first results on heteronuclear Bose-Bose Spin-Dynamics in the ^{7}Li-Na mixtures as well as in the Fermi-Bose ^{6}Li-Na mixture. The heteronuclear Bose-Bose system has the advantage that no dressing is needed to achieve energetic degeneracy due to the different quadratic Zeeman shift. The Fermi-Bose case, however, poses large experimental challenges since the energy-dependence on the magnetic field is of linear order, which requires high stability of magnetic fields.

Since the spin-exchange term for all these processes depends on the scattering lengths of the molecular states, we also present the first measurement of the Feshbach spectrum of ^{7}Li-Na which reveals a 1 G broad resonance at 150 G.

Q 58.89 Thu 16:30 Empore Lichthof

Spin phonon dynamics with classical statistical methods

— •Asier Piñeiro Orioli[1,2], Arghavan Safavi-Naini[2], Michael Wall[2], Johannes Schachenmayer[2], and Ana María Rey[2] — [1]Institute for Theoretical Physics, Heidelberg, Germany — [2]JILA, NIST and University of Colorado, Boulder, Colorado, USA

Systems with both spin and phonon degrees of freedom are ubiquitous in physical fields ranging from condensed matter to biophysics. However, methods to compute the dynamics of such systems are scarce, especially in high dimensions. In this work, we combine the Truncated Wigner Approximation (TWA) for bosons with its recently developed discrete version (dTWA) for spins to describe the dynamics of coupled spin-phonon systems. We benchmark the method by comparing to exact results and discuss applications to trapped-ion and cavity experiments.