Q 15: Poster: Quantum Optics and Photonics I

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

Q 15.1 Mon 17:00 C/Foyer

From short-time diffusive to long-time ballistic dynamics: the unusual center-of-mass motion of quantum bright solitons — •Christoph Weiss[1], Simon Gardiner[1], and Heinz-Peter Breuer[2] — [1]Joint Quantum Centre (JQC) Durham–Newcastle, Department of Physics, Durham University, Durham DH1 3LE, United Kingdom — [2]Physikalisches Institut, Universität Freiburg, Hermann-Herder-Straße 3, D-79104 Freiburg, Germany

Brownian motion is ballistic on short time scales and diffusive on long time scales. Our theoretical investigations indicate that one can observe the exact opposite — initially diffusive motion that becomes ballistic on longer time scales — in an ultracold atom system with a size comparable to macromolecules. This system is a quantum matter-wave bright soliton subject to decoherence via three-particle losses for which we investigate the center-of-mass motion. Our simulations show that such unusual center-of-mass dynamics should be observable on experimentally accessible time scales.

Q 15.2 Mon 17:00 C/Foyer

Matter-wave scattering from interacting ultracold bosons in optical lattices — Klaus Mayer, •Alberto Rodriguez, and Andreas Buchleitner — Physikalisches Institut, Albert-Ludwigs-Universität Freiburg, Hermann-Herder-Str. 3, 79104 Freiburg

We study matter-wave scattering from ultracold bosons in a one-dimensional optical lattice, described by a Bose-Hubbard Hamiltonian. The phase transition from the superfluid (SF) state to the Mott insulator (MI) is clearly displayed in the decay of the inelastic scattering cross-section for increasing onsite interaction U/J [1]. To understand the role of interactions in this process, we obtain analytical expressions for the cross-section from a Bogoliubov expansion, valid in the regime of small condensate depletion, and from a strong-coupling expansion, valid in the regime of large interactions U/J. This allows for the description of the inelastic cross-section's decay in the entire range of the relevant system parameters, excluding the vicinity of the critical point of the MI-SF phase transition. In the weak-interaction regime, the cross section is found to decay *linearly*, with a slope that is independent of the bosonic density and the system size [2]. In the strong-interaction regime, the decay is *quadratic* and vanishes only as $U/J \to \infty$, resulting in a non-vanishing inelastic cross section throughout the entire Mott phase. To support our analytical results, we present numerical studies obtained from exact diagonalization methods.

[1] S. Sanders, F. Mintert, E. Heller, PRL **105**, 035301 (2010)
[2] K. Mayer, A. Rodriguez, A. Buchleitner, PRA **90**, 023629 (2014)

Q 15.3 Mon 17:00 C/Foyer

Bose-Einstein condensation of ^{87}Rb in the $F = 2$, $m_F = 2$ state in a hybrid trap — •Adonis Flores, Hari Prasad Mishra, Wim Vassen, and Steven Knoop — LaserLaB, Department of Physics and Astronomy, VU University Amsterdam, The Netherlands

We have realized BEC of ^{87}Rb in the $F = 2$, $m_F = 2$ state in a hybrid trap [1], consisting of a weak quadrupole magnetic trap (QMT) at 15 G/cm and a single beam optical dipole trap (ODT) at 1557 nm with a waist of 40 μm and a maximum power of 4 W. The symmetry axis of the quadrupole magnetic trap coincides with the optical beam axis, which gives stronger axial confinement than previous hybrid traps. After loading 2×10^6 atoms at 14 μK from the QMT into the hybrid trap, we efficiently perform forced evaporation and reach the onset of BEC at a temperature of 0.5 μK and 4×10^5 atoms. We also obtain thermal clouds of 1×10^6 atoms below 1 μK in a pure single beam ODT, by ramping down the magnetic field gradient after evaporative cooling in the hybrid trap. We do not observe atoms in the $F = 2$, $m_F = 1$ state after evaporative cooling in the hybrid trap, which suggests that unwanted repopulation of this state during MW-evaporative cooling in the QMT does not take place, in contrast to harmonic magnetic traps. This is in particular relevant for our experimental scheme to realize an ultracold mixture of metastable triplet ^{4}He and ^{87}Rb [2]. Here we will also discuss the application of the hybrid trap for metastable He, and the preparation of the He+Rb mixture in an ODT.

[1] H. P. Mishra, A. S. Flores, W. Vassen, S. Knoop, arXiv:1411.7628
[2] S. Knoop *et al.*, Phys. Rev. A 90, 022709 (2014)

Q 15.4 Mon 17:00 C/Foyer

Decoherence of squeezed spatial superposition states of a BEC — •Björn Schrinski, Stefan Nimmrichter, and Klaus Hornberger — Physikalische Fakultät, Universität Duisburg-Essen

We study the influence of collisional decoherence and of macrorealistic collapse models on number-squeezed superpositions of Bose-Einstein condensates in a double-well configuration. These superpositions were recently produced in an experiment with ultracold Rubidium atoms [1]. Our analysis is based on a many-body generalization of the single-particle collisional decoherence master equation. It can be employed to assess the degree of macroscopicity [2] reached in such squeezed BEC interference experiments.

[1] Nat. Commun. 4, 2077 (2013)
[2] Phys. Rev. Lett. 110, 160403 (2013)

Q 15.5 Mon 17:00 C/Foyer

Ground State of Bose-Fermi Mixtures within Mean Field Approximation — •Christian Ufrecht, Albert Roura, Wolfgang P. Schleich, and the QUANTUS Team — Institut für Quantenphysik, Universität Ulm

In recent years, a large number of experiments with boson-fermion mixtures have been carried out. If the temperature is below a critical value then Bose-Einstein condensation occurs for bosons while it gives rise to a degenerate Fermi gas for fermions.

For polarized fermions and sufficiently high particle numbers, interacting boson-fermion mixtures can be described by a mean field theory for bosons combined with the Thomas-Fermi approximation for fermions.

Due to different values of the coupling parameter between bosons and fermions, we find a large variety of different ground states. By using geometric arguments we determine the qualitative densities, make statements about stability and derive analytic conditions for different ground state scenarios.

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

Q 15.6 Mon 17:00 C/Foyer

Expansion dynamics of dual-species Bose-Einstein condensates computed with co-moving grids — •Matthias Meister, Albert Roura, Wolfgang P. Schleich, and the QUANTUS Team — Institut für Quantenphysik, Universität Ulm

In recent years simultaneous Bose-Einstein condensation of different atomic species has been realized for a growing variety of mixtures. Hence, it is essential to develop new tools for a better theoretical understanding of these systems.

We present a numerical method for computing the ground state of a dual-species Bose-Einstein condensate and studying its expansion dynamics for arbitrarily long times after release from the trap. Our implementation builds upon ideas of ref. [1], which rely on performing a transformation to co-moving coordinates according to the scaling approach [2] instead of using a static grid in the lab frame. As a result we are left with a system that shows nearly no dynamics because the main contribution due to the expansion is encoded in the transformation. Thus, our simulations are not limited by the expansion time since the size of the condensate stays almost constant in the co-moving frame. Also, the remaining time evolution can be computed efficiently with only a few grid points as the wave functions are very smooth.

[1] M. Eckart, Non-equilibrium dynamics of trapped gases in controlled geometries, Ph.D. thesis, Universität Ulm, Ulm (2008)
[2] Y. Castin and R. Dum, Phys. Rev. Lett. **77**, 5315 (1996); Y. Kagan, E. L. Surkov and G. V. Shlyapnikov, Phys. Rev. A **54**, R1753 (1996) and Phys. Rev. A **55**, R18 (1997)

Q 15.7 Mon 17:00 C/Foyer

Collision studies in ultracold calcium atoms — •Hannes Winter, Purbasha Halder, and Andreas Hemmerich — Universität Hamburg

We present collision studies of metastable optically trapped calcium atoms and discuss the feasibility of achieving Bose-Einstein condensation in these states by evaporative cooling methods [1]. The metastable states of alkaline earth and rare earth elements have novel elastic and inelastic scattering prop-erties [2], with important implications for applications like time metrology and lattice-based quantum computing. The atoms are prepared by an alternative method analogous to the one used to create a ground state BEC [3]. We also discuss our new setup to realize a superradiant laser [4] similar to the proposal by [5].

References [1] P. Halder, H. Winter and A. Hemmerich, Phys. Rev. A 88, 063639 [2] V. Kokoouline et al., Phys. Rev. Lett. 90, 253201 (2003). [3] P. Halder, C.-Y. Yang and A. Hemmerich, Phys. Rev. A 85, 031603 (2012). [4] M. Holland and J. Thompson et al. Nature, 484(7392):78-81, (2012). [5] M. Holland et al., Phys. Rev. Lett. 102(16):163601, (2009).

Q 15.8 Mon 17:00 C/Foyer

Coherent Matter Wave Dynamics of BECs for Atom Interferometry and ATOMTRONICS Quantum Devices — •Felix Schmaltz, Johannes Küber, Dominik Lohrey, and Gerhard Birkl — Institut für Angewandte Physik, Technische Universität Darmstadt, Schlossgartenstraße 7, 64289 Darmstadt

We discuss our approach to establish a novel platform for the application of BEC-based coherent matter waves in toroidal guiding geometries for ATOMTRONICS devices (such as atomic SQUIDS), atom interferometry, and quantum simulation.

Our architecture is based on a novel type of toroidal dipole-force potential generated by conical refraction providing a pair of concentric annular intensity distributions. Depending on detuning, these serve as a concentric pair of red-detuned potential minima or as a single blue-detuned potential minimum. By changing the parameters of the refractive crystal and the impinging laser beam, the potential parameters, such as ring diameter and well dimensions can be varied with high flexibility. We coherently load and accelerate or split a BEC with Bragg diffraction in the confining potential.

For optimized manipulation of the BEC wavefunction, we implemented the recently proposed technique of 'Double Bragg Diffraction' as a robust and highly efficient beam splitter for coherent matter waves.

Q 15.9 Mon 17:00 C/Foyer

Bose-Einstein condensate in contact with an environment — •Alexander Schäbe and Corinna Kollath — Helmholtz-Institut für Strahlen- und Kernphysik, Nussallee 14-16, D-53115 Bonn

A famous feature of bosons is the formation of a condensate at low temperatures. Bose- Einstein condensates are used to investigate effects like phase transitions or its excitations e.g. solitons, vortices and breathing modes. Since there is a variety of excitations of the condensate, it is a research field of great interest.

In the experimental setups, typically, effects of the coupling to the environment need to be taken into account. These can be e.g. atom loss events or heating effects. We investigate such environmental effects onto a BEC. A condensate can be generally described by the solution of the Gross-Pitaevskii (GP) equation which takes a trapping potential and the interaction of the bosons into account. Further, the GP equation can be modified in order to include the loss of atoms. By a numerical treatment of such a system, we will study all the dynamics and consequences, which are induced by dissipation.

Q 15.10 Mon 17:00 C/Foyer

Correlated Quantum Dynamics of a Single Atom Collisionally Coupled to an Ultracold Finite Bosonic Ensemble — Sven Krönke[1], •Johannes Knörzer[1], and Peter Schmelcher[1,2] — [1]Zentrum für Optische Quantentechnologien, Universität Hamburg — [2]The Hamburg Centre for Ultrafast Imaging

We explore the correlated quantum dynamics of a single atom with a spatio-temporally localized coupling to a finite bosonic ensemble. The single atom is initially prepared in a coherent state and oscillates in a one-dimensional harmonic trap. An ensemble of N_A interacting bosons is trapped in a separated harmonic potential. The ensemble is periodically penetrated by the single atom. The non-equilibrium quantum dynamics of the total system is simulated by means of an *ab-initio* method. In this poster presentation, we focus on characterizing the impact of the spatio-temporally localized inter-species coupling and the thereby induced inter-species correlations on the states of the single atom and the finite bosonic ensemble. With increasing N_A, we observe an accelerated inter-species energy transfer due to a level splitting induced by inter-species interactions. The ensemble mainly features singlet and doublet excitations and a delayed emergence of doublets is observed for which we offer analytical insights with a stroboscopic time-dependent perturbation theory. At instants of not too imbalanced energy distribution among the subsystems, inter-species correlations prove to be significant. We relate those instants to the coherence of the single atom quantum state indicating that correlated energy transfer dynamics manifests itself in temporal losses of its coherence.

Q 15.11 Mon 17:00 C/Foyer

Optimization of an Ultracold Quantum Gas Experiment by Artificial Evolution — •Tobias Lausch[1], Michael Bauer[1], Farina Kindermann[1], Daniel Mayer[1,2], Felix Schmidt[1,2], and Artur Widera[1,2] — [1]TU Kaiserslautern and Forschungszentrum OPTIMAS, Erwin-Schroedinger Str. 46, 67663 Kaiserslautern, Germany — [2]Graduate School Materials Science in Mainz,Gottlieb-Daimler-Straße 47, 67663 Kaiserslautern, Germany

Quantum mechanical measurements in ultracold gas experiments require many repetitions for good statistics and therefore short cycle times. The production time of a BEC can be improved in many ways. Increasing, for instance, loading rates in the magneto-optical trap (MOT) or the transfer efficiency from the MOT to the optical dipole trap by adjusting laser detunings, intensities or more complex parameters such as the shape of the evaporation ramp.

In order to automatize the optimization process, we implement an evolutionary algorithm. The basic working principle, the survival of the fittest, is enhanced by differential evolution. The algorithm is designed to improve any measurable feedback with a given set of parameters. By analyzing the data obtained, knowledge about constraints of the experimental setup and significance of the parameters is gained as well as a set of optimal values for the creation of a BEC.

Q 15.12 Mon 17:00 C/Foyer

Universal self-similar dynamics of relativistic and non-relativistic field theories near non-thermal fixed points — •Asier Piñeiro Orioli[1], Kirill Boguslavski[1], and Jürgen Berges[1,2] — [1]Institut für Theoretische Physik, Universität Heidelberg, Philosophenweg 16, 69120 Heidelberg, Germany — [2]ExtreMe Matter Institute EMMI, Planckstraße 1, 64291 Darmstadt, Germany

The dynamics of quantum fields far from equilibrium play an important role in systems ranging from early universe cosmology and relativistic heavy-ion collisions to ultra cold quantum gases. Strikingly, universal features emerge during the respective thermalisation processes. This universality is based on the existence of non-thermal fixed points, which are attractor solutions characterised by turbulence and self-similar time evolution. In this talk we will show that the (massless) relativistic and the non-relativistic (Gross-Pitaevskii) scalar field theory belong to the same universality class in the infrared. We compute the scaling exponents and scaling functions in this non-perturbative regime in two ways: first by performing classical statistical lattice simulations and second by using the resummed 2PI $1/N$ expansion to NLO.

Q 15.13 Mon 17:00 C/Foyer

Stabilization and site-resolved imaging of a few-fermion system — •Vincent M. Klinkhamer[1], Justin F. Niedermeyer[2], Andrea Bergschneider[1], Simon Murmann[1], Gerhard Zürn[1], and Selim Jochim[1] — [1]Physikalisches Institut der Universität Heidelberg, Im Neuenheimer Feld 226, 69120 Heidelberg, Germany — [2]Department of Physics and Astronomy, Washington State University, Pullman, WA, USA

In our few-fermion experiment, we manipulate a small number of interacting particles inside a variable optical trap. In order to expand the size of our system, we have improved the stability of our optical trap and implemented site-resolved imaging.

We create arrays of dimple traps by diffracting our trapping laser beam with an acousto-optic deflector (AOD). Thermal fluctuations and drifts with timescales between milliseconds and hours cause significant variations in the relative trap depths. We address this problem by monitoring the light of the trapping potential on a camera and feeding back to the AOD in real time.

After performing our experiments, we measure the outcome by taking a fluorescence image of our atoms. We can determine the atom number from the strength of the fluorescence signal, however, the photon recoil causes the atoms to diffuse. We plan to circumvent this by reducing the exposure time and imaging the scattered photons on an EMCCD. To identify the signal of the atoms on the image we apply a pattern-recognition algorithm.

Q 15.14 Mon 17:00 C/Foyer

Study of Phase Correlations in Trapped 2D Interacting Quantum Gas — •Dhruv Kedar, Luca Bayha, Puneet Murthy, Mathias Neidig, Martin Ries, Andre Wenz, Gerhard Zürn, and Selim Jochim — Physikalisches Institut, Universität Heidelberg

We study the phase correlations of a two dimensional strongly interacting ultracold gas of Lithium 6. In 3D true long range order and a constant phase is predicted in the superfluid low temperature phase. This differs from the physics in 2D where for uniform systems long range order is destroyed due to thermal fluctuations at finite temperatures. Instead, Berezinskii Kosterlitz Thouless (BKT) theory predicts a qualitative change from exponential to algebraically decaying coherence when the gas crosses the transition to the superfluid phase. Our measurements are in qualitative agreement with the theory. We extract a trap averaged spatial correlation function from the the pair momentum distribution for our inhomogeneous 2D system. We observe that the obtained algebraic decay differs from the behaviour expected for a homogeneous system, but is in agreement with QMC simulations for a trapped Bose gas.

Q 15.15 Mon 17:00 C/Foyer

Exploring few-fermion systems in single- and multi-well potentials — •Andrea Bergschneider, Simon Murmann, Vincent M. Klinkhamer, Gerhard Zürn, and Selim Jochim — Physikalisches Institut der Universität Heidelberg, Im Neuenheimer Feld 226, 69120 Heidelberg, Germany

We study fermionic systems in the transition from microscopic to mesoscopic size. To do this, we start with the smallest realization that contains the relevant physics and then gradually increase the size of the system. Here, we present several experiments to investigate this cross-over and the methods we use.

We can deterministically prepare balanced and spin-polarized few-fermion systems in the ground state of a single well having full control over their quantum state. We can control the confinement of the potential and also create multiple wells. Furthermore, our system allows us to tune the interactions between the fermions over a large range. To probe it, we detect the number and spin of atoms in the potential wells site-selectively and measure the energy of the system.

With our setup, we study the physics of one impurity interacting with an increasing number of majority particles. It also allows us to prepare two fermions in the ground state of the double well and observe the occupation statistics as a function of the interaction strength.

Q 15.16 Mon 17:00 C/Foyer

Towards strongly interacting ultracold dimers in an optical two–dimensional square lattice — •Luca Bayha, Dhruv Kedar, Puneet Murthy, Mathias Neidig, Martin Ries, Andre Wenz, Gerhard Zürn, and Selim Jochim — Physikalisches Institut, Universität Heidelberg

We start from a strongly interacting superfluid of ^{6}Li Feshbach-dimers in the quasi 2D regime. The goal is to load this system into an optical square lattice, produced by two laser beams which are retro-reflected under a small angle. One of the main experimental challenges are the very strong interactions. In the investigated regime the scattering length is on the order of the lattice period. Hence, the simple Bose-Hubbard model is expected to be modified. On this poster we summarize our current progress towards this goal.

Q 15.17 Mon 17:00 C/Foyer

Time-dependant isospin correlations in two-partite hexagonal optical lattices — •Holger Niehus, Eva-Maria Richter, Marta Prada, and Daniela Pfannkuche — I. Institut für Theoretische Physik, Universität Hamburg, Jungiusstr. 9, 20355 Hamburg, Deutschland

Multi-component systems of ultracold quantum gases in optical lattices have shown a variety of new and interesting quantum phases. A simple system for investigating (iso-)magnetic phases is a two-component mixture, modeled by a Bose-Hubbard Hamiltonian with component interaction of the form $\hat{H}_{\text{int}} = \sum_i V \hat{n}_A^i \hat{n}_B^i$. Employing exact numerical methods and mapping occupation differences of the two components to an effective spin, we were able to calculate iso-magnetic correlations. This enabled us to identify and characterise the different phases of the system on the full range of Hubbard interaction parameters [1].

Recently there has been a growing interest in the dynamics of systems far from equilibrium. Here, we study the dynamics of the two-component system with regard to sudden changes in the interaction strengths. The time evolution of the iso-magnetic correlations will be analyzed with respect to characteristic low energy excitations.

[1] M. Prada, E.-M. Richter, D. Pfannkuche, Phys. Rev. A. **90**, 013613 (2014).

Q 15.18 Mon 17:00 C/Foyer

Towards multi-body entanglement in optical lattices — Hanning Dai[1,2], •Bing Yang[1,2], Xiaofan Xu[1], Andreas Reingruber[1], Qi Shen[2], Zhensheng Yuan[2], and Jianwei Pan[1,2] — [1]Physikalisches Institut, University Heidelberg — [2]Hefei National Laboratory for Physical Science at Microscale and Department of Modern Physics, University of Science and Technology of China

Neutral atoms in optical lattices have the advantage of a natural scalability towards large qubit numbers and a weak coupling to the environment, leading to long decoherence time. However, the creation of multi-partite entanglement and the unambiguous characterization of it in optical lattices still remain challenging.

Here we propose an experiment towards the perparation of a 4-qubit GHZ-type state in an optical plaquette and introduce the progress of the project. Recently, by using two superlattices along perpendicular directions, a four-site optical plaquettes have been realized. By employing a spin-dependent superlattice, one can achieve state initialization as well as spin and site resolved addressing and detection, the key prerequisites to prepare and observe multi-body correlations in optical lattices.

Q 15.19 Mon 17:00 C/Foyer

Quantum Simulation of Lattice Gauge Theories Out of Equilibrium — •Valentin Kasper[1], Florian Hebenstreit[2], Markus Oberthaler[3,4], and Jürgen Berges[1,4] — [1]Institut für Theoretische Physik, Ruprecht-Karls-Universität Heidelberg, Philosophenweg 16, 69120 Heidelberg — [2]Universität Bern - Albert Einstein Center for Fundamental Physics (AEC) Sidlerstrasse 5, CH-3012 Bern, Switzerland — [3]Kirchhoff-Institute for Physics, Ruprecht-Karls-Universität Heidelberg, Im Neuenheimer Feld 227, 69120 Heidelberg — [4]ExtreMe Matter Institute EMMI, GSI Helmholtzzentrum für Schwerionenforschung, Planckstraße 1, 64291 Darmstadt, Germany

Quantum link models have been proposed as an alternative regularization of lattice gauge field theories. The U(1) quantum link models are constructed by replacing the parallel transporters of Wilsonian lattice gauge theory with quantum spin operators acting on 2S+1 states per link. The original gauge theory is recovered in the limit of large representations $S \to \infty$. Due to the dramatic increase of the size of the Hilbert space, investigating the dynamics of these models for $S \gg 1$ becomes difficult. We study the limit of large spin representations by a functional integral approach and report on the transition from finite S to $S \to \infty$. As a specific application, we present results on the dynamical version of the Schwinger effect.

Q 15.20 Mon 17:00 C/Foyer

Quench dynamics of ultracold fermions in hexagonal lattices — •Nick Fläschner, Dominik Vogel, Matthias Tarnowski, Benno Rem, Christof Weitenberg, and Klaus Sengstock — Institut für Laserphysik, Universität Hamburg

Ultracold fermions are ideally suited to test solid-state theories since many system parameters can be easily tuned. It is, however, often difficult to adiabatically prepare the respective ground state, which can, e.g., be due to technical lifetime limitations or when band gaps close at the phase transition point. Even if the ground state can be experimentally reached, it is often challenging to find suitable observables for characterizing the Hamiltonian. Addressing both of these limitations, we start in a spin-polarized fermionic band-insulator, perform a quench of various lattice parameters and observe the following dynamics in momentum space. This allows for a full reconstruction of the Hamiltonian of the quenched system in a momentum-resolved fashion, paving the way towards the experimental investigation of yet inaccessible ground states, also in the presence of interactions.

Q 15.21 Mon 17:00 C/Foyer

Exploring anti-ferromagnetic correlations of ultracold fermions in varying optical lattice geometries — •Gregor Jotzu, Daniel Greif, Michael Messer, Frederik Görg, Rémi Desbuquois, and Tilman Esslinger — Institute for Quantum Electronics, ETH Zurich, 8093 Zurich, Switzerland

Ultracold fermions in optical lattices are an ideal toolbox for studying open questions in quantum magnetism in various lattice geometries, ranging from simple cubic to honeycomb and spin ladder configurations. While not only allowing for a highly controlled approach to the thermodynamic properties, the cold atoms approach can also give insight into the dynamic properties of the system and even the response to smooth changes of the underlying lattice geometry.

We load a fermionic quantum gas of K-40 prepared in a balanced, two-component spin mixture into a tunable-geometry optical lattice. We observe the formation of anti-ferromagnetic spin correlations in various geometries, including simple cubic, square, honeycomb and spin-ladder configurations. Our findings demonstrate that quantum magnetism can be realized and studied with ultracold atoms in a broad variety of lattice geometries. Additionally, we demonstrate first experimental results on the dynamics of spin correlations.

Q 15.22 Mon 17:00 C/Foyer

Realizing spin-dependent lattices for ultracold atoms with magnetic gradient modulation — •Frederik Görg, Gregor Jotzu, Michael Messer, Rémi Desbuquois, Daniel Greif, and Tilman Esslinger — Institute for Quantum Electronics, ETH Zurich, 8093 Zurich, Switzerland

Time-modulated optical lattices have been demonstrated to allow for the dynamical control of atomic tunneling and the realization of effective lattice Hamiltonians with a non-trivial topological band structure. In order to realize spin-dependent Hamiltonians, an oscillating magnetic gradient can be used, which couples differently to the individual spin components of the atomic gas owing to the difference in magnetic moments. This allows for the realization of spin-dependent lattices due to the selective renormalization of the tunneling amplitudes of each spin component. In this way, situations where one spin component is pinned to the lattice and the other one remains itinerant are achievable. Furthermore, the combination of an oscillating gradient with a time-modulation of the optical lattice allows for tailoring Hamiltonians with nontrivial topological properties. As an example, the use of two spin components with opposite magnetic moments realizes the celebrated Kane-Mele model.

Q 15.23 Mon 17:00 C/Foyer

Investigating a strongly correlated quantum gas with competing short-range and cavity-mediated long-range interactions — •Lorenz Hruby, Renate Landig, Nishant Dogra, Rafael Mottl, Tobias Donner, and Tilman Esslinger — ETH Zürich, Zürich, Schweiz

We report on our study of superfluid, supersolid and Mott-insulating phases and the corresponding quantum phase transitions in a quantum gas coupled to an optical high-finesse cavity. The cavity mediates long-range interactions, whereas additional classical optical lattices give rise to short-range interactions. We investigate the competition between these short- and long-range interactions, which results in a rich phase diagram going beyond the classical Bose-Hubbard phase diagram. The openness of the cavity allows us to extract real - time information on atomic density fluctuations and excitations in the system.

Q 15.24 Mon 17:00 C/Foyer

Theoretical study of the Bose-Hubbard model in the presence of cavity-mediated long-range interactions — •Nishant Dogra[1], Ferdinand Brennecke[2], Rafael Mottl[1], Lorenz Hruby[1], Renate Landig[1], Sebastian Huber[3], Tobias Donner[1], and Tilman Esslinger[1] — [1]HPF D4, Quantum Optics Group, Institute for Quantum Electronics, ETH Zurich,Otto-Stern-Weg-1,Zurich-8093 — [2]Physikalisches Institut, Universität Bonn, Wegelerstrasse 8, Bonn-53115 — [3]HIT K 23.4, Institute for Theoretical Physics, ETH Zurich, Wolfgang-Pauli-Strasse 27, Zurich-8093

The Bose-Hubbard model has been a paramount example of quantum simulation of many-body systems. It is realized by loading a quantum gas in a 3D optical lattice. This system undergoes a phase transition from superfluid to the Mott-insulator phase due to the competition between the kinetic energy and the short-range interactions. We study the effect of long-range interactions on this system generated by strongly coupling the quantum gas to a high finesse cavity and pumping it with a transverse laser field. This system can be mapped to an extended Bose-Hubbard model. In the limit where the classical lattice is commensurate with the cavity generated dynamical lattice, we calculate the phase diagram of this system using different mean-field approaches. We find that the cavity-mediated long-range interactions give rise to additional phases: charge density wave insulator and supersolid phase. We also calculate the excitation spectrum of these phases and relate it to the nature of the transition between them. We further briefly discuss the status of the experimental implementation of this scheme.

Q 15.25 Mon 17:00 C/Foyer

A novel experiment for coupling a Bose-Einstein condensate with two crossed cavity modes — •Philip Zupancic, Julian Leonard, Andrea Morales, Tilman Esslinger, and Tobias Donner — ETH Zürich, Schweiz

Cavity QED has proven to be a very attractive research area to explore many-body physics using quantum degenerate gases. Over the last decades, the coupling of single atoms, cold ensembles of atoms and Bose-Einstein condensates (BEC) to single modes of the electromagnetic field has been successfully exploited and investigated. To push the research further in this direction we built a novel system involving two intersecting cavities. With this setup we are able to couple a BEC of 87-Rb atoms to two spatially distinct modes of the electromagnetic field. The ultracold cloud is optically transported into the crossed cavity setup by means of a novel designed optical dipole trap involving focus-tunable lenses. Our lens setup allows to change the position of the trap while keeping its waist, and therefore the overall trapping conditions, constant.

We report on recent progress on the implementation of a cavity setup involving two high-finesse optical resonators intersecting under an angle of 60°. The mirrors have been fabricated in order to spatially approach them, thus obtaining maximum single atom coupling rates of several MHz. This setup will allow us to study the coherent interaction of a BEC and the two cavity modes both in internal lambda-level transitions and in spatial self-organization processes in dynamical hexagonal lattices.

Q 15.26 Mon 17:00 C/Foyer

Experimental and theoretical study of the topological Haldane model — •Michael Messer, Gregor Jotzu, Rémi Desbuquois, Martin Lebrat, Thomas Uehlinger, Frederik Görg, Daniel Greif, and Tilman Esslinger — Institute for Quantum Electronics, ETH Zurich, 8093 Zurich, Switzerland

The Haldane model is a fundamental example of a Hamiltonian exhibiting topologically distinct phases of matter and featuring a quantum Hall effect without a net magnetic field. We report on the experimental realisation of the Haldane model and the characterisation of its topological band-structure, using non-interacting ultracold fermionic atoms in a periodically modulated honeycomb lattice. We explore the resulting Berry-curvatures of the lowest band and map out topological phase transitions connecting distinct regimes. We furthermore relate our experimental study of the topological Haldane model to the analytical and numerical calculation of an effective Hamiltonian for time-modulated optical lattices. Using Floquet theory, we derive the mapping from a modulated honeycomb lattice to the Haldane Hamiltonian.

Q 15.27 Mon 17:00 C/Foyer

An experiment for long-range interacting fermionic gases in reduced dimensions — •Stephan Helmrich, Alda Arias, Nils Pehoviak, Christoph Schweiger, and Shannon Whitlock — Physikalisches Institut, Universität Heidelberg, Im Neuenheimer Feld 226, 69120 Heidelberg

We are building a new experiment for the quantum simulation of strongly-correlated fermionic systems with long-range interactions. To introduce and control the interactions we aim to optically admix a small Rydberg state component to the ground state of the atoms ("Rydberg dressing"). This would allow full control over the range and strength of the interactions, combined with long lifetimes of the atomic states.

We will use fermionic quantum gases of potassium-40 combined with high resolution fluorescence imaging of the individual atoms to directly measure spatial correlations. Our initial focus will be on realising exotic quantum phases in one-dimensional traps and at the crossover to two dimensions. Through complete access to the microscopic degrees of freedom, this experiment will allow for studies of quantum effects in complex many-body systems, including the role of entanglement near quantum phase transitions and the emergence of macroscopic effects such as superfluidity and quantum magnetism.

Q 15.28 Mon 17:00 C/Foyer

Real-Space Dynamical Mean-Field Theory of the SU(4)-symmetric fermionic Hubbard model and its extensions. Magnetic orderings and Hund's coupling. — •Agnieszka Cichy[1], Andrii Sotnikov[2], and Walter Hofstetter[1] — [1]Goethe Universität, Frankfurt a. M., Germany — [2]Kharkiv Institute of Physics and Technology, Kharkiv, Ukraine

The impressive development of experimental techniques in ultracold quantum degenerate gases of alkaline-earth atoms in the last years has allowed investigation of strongly correlated systems. Long-lived metastable states in combination with a decoupled nuclear spin give the opportunity to study Hamiltonians beyond the possibilities of current alkali-based experiments such as: two-band Hubbard models, the Kondo lattice model as well as SU(N)-symmetric magnetic systems. From the experimental point of view Ytterbium is the most appropriate due to its large number of bosonic and fermionic (e.g. ^{173}Yb) isotopes with a wide range of interaction strengths. We study finite-temperature properties of four-component mixtures of ultracold fermions within the repulsive ($U > 0$) Hubbard model, on the simple cubic lattice. We use the Real-Space Dynamical Mean-Field method, mostly for the half-filling case and at intermediate and strong couplings. We also investigate the case of different interspecies interactions and its influence on the possible magnetic orderings. Finally, we study the role of Hund's coupling (exchange interaction) in finite temperature magnetic phases, within two-band Hubbard model.

Q 15.29 Mon 17:00 C/Foyer

Detection of topological order in interacting many-body systems using mobile impurities — •Fabian Grusdt[1,2,3], Norman Yao[3], Dmitry Abanin[3,4,5], and Eugene Demler[3] — [1]Department of Physics and research center OPTIMAS, University of Kaiserslautern, Germany — [2]Graduate School Materials Science in Mainz, Kaiserslautern, Germany — [3]Department of Physics, Harvard University, Cambridge, Massachusetts 02138, USA — [4]Perimeter Institute for Theoretical Physics, Waterloo, Canada — [5]Institute for Quantum Computing, Waterloo, Canada

We present a scheme for the detection of topological order in interacting many-body systems. Our method is based on a generalization of single-particle interferometric schemes developed for the detection of topological invariants of band structures [Atala et.al., Nature Physics 9, 795 (2013)]. We suggest to couple a spin-1/2 impurity to a (topological) excitation of the many-body system. Performing Ramsey interferometry in combination with Bloch oscillations of the resulting composite particle (a strong-coupling topological polaron) allows to directly detect many body-topological invariants. We demonstrate the feasibility of our scheme by discussing integer and fractional Chern insulators in two dimensions, and show how fractionalized excitations can be detected. We also consider one-dimensional systems and show how symmetry-protected topological invariants can be measured.

Q 15.30 Mon 17:00 C/Foyer

Steady State Currents in the Driven Dissipative Bose-Hubbard Model — •Thomas Mertz[1], Ivana Vasic[1,2], Daniel Cocks[1,3], and Walter Hofstetter[1] — [1]Institute for Theoretical Physics, Goethe-University, Frankfurt am Main, Germany — [2]Institute of Physics, University of Belgrade, Beograd, Serbia — [3]School of Engineering and Physical Sciences, James Cook University, Townsville, Australia

Non-equilibrium dynamics of interacting bosons has been explored intensely in recent experiments in both cold atoms and quantum optical systems. We study the driven Bose-Hubbard model with one-body loss in two dimensions for both spatially homogeneous and inhomogeneous coupling to the environment. We describe dissipation by coupling the system to a Markovian bath in terms of a Lindblad master equation for the reduced density operator. In our work we analyse the steady states of such systems, in particular we consider steady states that exhibit constant particle currents supported by inhomogeneous coupling to the environment. Furthermore, we investigate the effect of the bath parameters on the occurence of constant currents.

Q 15.31 Mon 17:00 C/Foyer

Superfluid Phases in the Presence of Artificial Gauge Fields — •Rajbir Nirwan[1], Ivana Vasic[1,2], Alex Petrescu[3,4], Karyn Le Hur[4], and Walter Hofstetter[1] — [1]Institut für Theoretische Physik, Frankfurt, Germany — [2]Institute of Physics Belgrade, Belgrade, Serbia — [3]Department of Physics, Yale, USA — [4]Centre de Physique Theorique, Ecole Polytechnique, France

In recent years several experiments have reported the realization of artificial gauge fields in systems of cold atoms in optical lattices. One of the latest advances has been the realization of the Haldane model [1,2]. Motivated by these achievements, we investigate the Haldane model for bosons in the weakly interacting regime using the Gross Pitaevskii- equation [3]. We study the ground state of the system and find two different superfluid phases. In the normal superfluid phase the ground state of the system is a Bose-Einstein condensate at zero quasi-momentum. However, for sufficiently strong next-nearest neighbor hopping we find a chiral superfluid phase, where the ground state of the system consists of two condensates formed at finite quasi-momentum. In both cases we calculate the pattern of local mass currents and density distributions.

[1] F. D. M. Haldane, Phys. Rev. Lett. 61, 2015 (1988)
[2] G. Jotzu, M. Messer, R. Desbuquois, M. Lebrat, T. Uehlinger, D. Greif, and T. Esslinger, Nature (London) 515, 237 (2014)
[3] I. Vasic, A. Petrescu, K. Le Hur, W. Hofstetter, arXiv: 1408.1411

Q 15.32 Mon 17:00 C/Foyer

Direct observation of chiral order in double layer superfluid — •Arne Ewerbeck, Carl Hippler, Thorge Kock, Robert Büchner, Raphael Eichberger, Matthias Ölschläger, Wen-Min Huang, Ludwig Mathey und Andreas Hemmerich — Institut für Laseryphsik, Hamburg

A double layer chiral superfluid is formed in the second band of a bipartite optical square lattice. In an ballistic expansion process the two layers are superimposed. The Bragg maxima thus observed exhibit interference patterns, which provide direct information on the formation of chiral order and the presence and character of low energy excitations.

Q 15.33 Mon 17:00 C/Foyer

Quasi-Condensation and Superfluidity in a Ring Trap — Hansjörg Polster and •Carsten Henkel — University of Potsdam, Germany

Low-dimensional Bose gases suffer from large phase fluctuations that prevent the formation of a proper condensate as defined by Penrose and Onsager. We study a one-dimensional, phase-fluctuating gas in the cross-over region between the ideal gas and the quasi-condensate (weak interactions). Correlation functions of any order are found by mapping the quantum field theory to a random walk in the complex plane, making a classical field approximation [1]. We discuss in particular full distribution functions for the atomic density, including the formation of pairs and clusters at the onset of quasi-condensation. Currently we investigate the distribution function of the total particle current in a rotating ring trap [2] which provides insight into the superfluid behaviour of the gas.

[1] L. W. Gruenberg and L. Gunther, *Phys. Lett. A* **38** (1972) 463; D. J. Scalapino, M. Sears, and R. A. Ferrell, *Phys. Rev. B* **6** (1972) 3409
[2] I. Carusotto and Y. Castin, *C. R. Physique* **5** (2004) 107

Q 15.34 Mon 17:00 C/Foyer

Failure of extended mean-field theories in one-dimensional Bose gases — Tim Sauer and •Carsten Henkel — University of Potsdam, Germany

Due to large thermal fluctuations, low-dimensional Bose gases do not develop a proper condensate, and even the onset of quasi-condensation turns into a cross-over rather than a phase transition. This is actually a challenge to reproduce within a mean-field theory because the modeling of the system seems to require a larger number of relevant hydrodynamic fields. In other words, the statistics of the quantum field is far from Gaussian in the cross-over region. We outline a zoology of mean-field theories [1,2] and develop efficient analytical formulas using a high-temperature expansion. The problems of the theories are illustrated by studying the equation of state and density fluctuations.

[1] C. Mora and Y. Castin, *Phys. Rev. A* **67** (2003) 053615.
[2] R. Walser, *Opt. Commun.* **243** (2004) 107

Q 15.35 Mon 17:00 C/Foyer

Quench-condensation of one-dimensional Bose gases — •Sebastian Erne[1,2,4], Thomas Gasenzer[1,2,3], and Jörg Schmiedmayer[4] — [1]Institut für Theoretische Physik, Ruprecht-Karls-Universität Heidelberg, Philosophenweg 16, 69120 Heidelberg, Germany — [2]ExtreMe Matter Institute EMMI, GSI Helmholtzzentrum für Schwerionenforschung GmbH, Planckstraße 1, 64291 Darmstadt, Germany — [3]Kirchhoff-Institut für Physik, INF 227, 69120 Heidelberg, Germany — [4]Vienna Center for Quantum Science and Technology (VCQ), Atominstitut, TU Wien, Vienna, Austria

This work investigates the rapid cooling quench over the dimensional- and quasicondensate-crossover. Following experiments performed by R. Bücker, W. Rohringer *et.al* at the Atominstitut in Vienna, we study the relaxation of such a far-from equilibrium system. The early stage of condensate formation is dominated by solitonic excitations. The high density of these defects lead to a characteristic exponential momentum distribution as well as stability of the condensate towards exterior pertubations. Experimental and numerical results are compared to analytical predictions drawn from our model of randomly distributed defects. Complete thermalization of the system is observed through measurements of the momentum distribution, exhibiting a transition from the random defect to a modifed Yang-Yang model.

Q 15.36 Mon 17:00 C/Foyer

Universal dynamics and non-thermal fixed points in spinor Bose-Einstein condensates — •Anselm Klenner[1,2,3], Markus Karl[1,2,3], and Thomas Gasenzer[1,2,3] — [1]Kirchhoff-Institut für Physik, Ruprecht-Karls-Universität Heidelberg, Im Neuenheimer Feld 227, 69120 Heidelberg, Germany — [2]Institut für Theoretische Physik, Ruprecht-Karls-Universität Heidelberg, Philosophenweg 16, 69120 Heidelberg, Germany — [3]ExtreMe Matter Institute EMMI, GSI Helmholtzzentrum für Schwerionenforschung GmbH, Planckstraße 1, 64291 Darmstadt, Germany

Using numerical simulations we investigate second order phase transitions of spin-1 spinor Bose-Einstein condensates. For the simulations we use the truncated Wigner method which is a statistical approach and uses classical field equations. The spinor condensates provide us with a rich variety of phases and topological defects such as domain walls, spin textures and spin vortices. The types of defects which are created depend on the properties of the critical point. In these simulations we can reach states with quasi-stationary, non-equilibrium momentum distributions, which indicate the vicinity of a non-thermal fixed point. Spinor Bose gases provide ideal means to study such universal critical dynamics far from equilibrium, which is expected to be relevant for a wide range of phenomena far beyond ultracold gases.

Q 15.37 Mon 17:00 C/Foyer

Dynamical universal properties of one-dimensional split condensates — •Sebastian Erne[1,2,4], Valentin Kasper[1], Jürgen Berges[1], Thomas Gasenzer[1,2,3], and Jörg Schmiedmayer[4] — [1]Institut für Theoretische Physik, Ruprecht-Karls-Universität Heidelberg, Philosophenweg 16, 69120 Heidelberg, Germany — [2]ExtreMe Matter Institute EMMI, GSI Helmholtzzentrum für Schwerionenforschung GmbH, Planckstraße 1, 64291 Darmstadt, Germany — [3]Kirchhoff-Institut für Physik, INF 227, 69120 Heidelberg, Germany — [4]Vienna Center for Quantum Science and Technology (VCQ), Atominstitut, TU Wien, Vienna, Austria

The recent measurement of higher-order phase correlation functions enables a precise examination of non-Gaussian correlations in the relative phase of two one-dimensional quasicondensates. This shows the necessity of refined non-pertubative theoretical descriptions of split condensates. For these systems the early time evolution of squeezed states is well described by a quadratic theory. In this work we investigate how the linear coupling between two one-dimensional Bose gases controls the non-Gaussian contributions. The subsequent quench of this control parameter can proceed in two directions: Increasing or decreasing the non-gaussianity of the systems as compared to the initial state. Finally we report on universal properties of the dynamics of higher-order correlation functions.

Q 15.38 Mon 17:00 C/Foyer

Nonthermal fixed points and superfluid turbulence in 2D ultracold Bose gases — •Fabian Brock[1,2], Simon Sailer[1,2], Markus Karls[1,2], and Thomas Gasenzer[1,2] — [1]Kirchhoff-Institut für Physik, Im Neuenheimer Feld 227, 69120 Heidelberg — [2]Institut für Theoretische Physik, Ruprecht-Karls-Universität Heidelberg, Philosophenweg 16, 69120 Heidelberg

The behavior of turbulent one-component Bose-Einstein condensates is studied by simulations of the driven-dissipative Gross-Pitaevskii equation and free expansion dynamics. The aspect ratio during free expansion is studied using the GPE and a hydrodynamic model based on Eulers equations. By comparison to non-turbulent systems, this gives insight into the influence of vorticity on the expansion dynamics. The results aim to help the study of superfluid turbulence in experiment by measuring the gas after some given expansion time and drawing inferences on its initial state. In the driven-dissipative case, non-thermal fixed points far away from equilibrium are studied. Power laws in the occupation number are numerically determined by vortex statistics and compared to analytical results.

Q 15.39 Mon 17:00 C/Foyer

Towards a degenerate quasi 2D gas of fermions near the BEC-BCS crossover — •Thomas Paintner, Daniel Hoffmann, Stefan Häusler, Wladimir Schoch, Wolfgang Limmer, Benjamin Deissler, and Johannes Hecker-Denschlag — Universität Ulm, Institut für Quantenmaterie, Deutschland

Here, we present the creation of a two-dimensional gas of ultracold fermions near the BEC-BCS crossover.

We prepared a sample of ultracold ^{6}Li atoms in the lowest two hyperfine states in a strong single beam optical dipole trap. For implementing a quasi 2D degenerate gas we focus a blue detuned TEM_{01} beam on our atoms [1].

To create the TEM_{01}, we illuminate a π-phase plate with a high power laser at 532nm. In the far field a TEM_{01} profile is created. We can change the size of the TEM_{01} mode by changing the laser beam waist. Strong enough confinement of the atoms in the TEM_{01} laser field will freeze out the atomic motion in this direction, leading to a quasi 2D gas.

Reducing the dimension of the system is another major step towards the realization of an all optical 2D honeycomb lattice.

[1] Opt.Express 13, 2843-2851 (2005)

Q 15.40 Mon 17:00 C/Foyer

Time-of-Flight Expansion for Trapped Dipolar Fermi Gases: From Collisionless to Hydrodynamic Regime — •Vladimir Veljić[1], Antun Balaž[1], and Axel Pelster[2] — [1]Scientific Computing Laboratory, Institute of Physics Belgrade, University of Belgrade, Serbia — [2]Physics Department and Research Center OPTIMAS, Technical University of Kaiserslautern, Germany

Some time ago it was predicted that the momentum distribution of a Fermi gas is deformed from spherical to cyclindrical provided a dipole-dipole interaction is present. A recent time-of-flight (TOF) expansion experiment has now unambiguously detected such a Fermi surface deformation in a dipolar quantum gas of fermionic erbium atoms in the collisionless regime [1]. Here we follow Ref. [2] and perform a systematic study of TOF expansions for trapped dipolar Fermi gases ranging from the collisionless to the hydrodynamic regime at zero temperature. To this end we solve analytically the underlying Boltzmann-Vlasov equation in the vicinity of equilibrium by using a suitable rescaling of the equilibrium distribution, where the collision integral is simplified within a relaxation-time approximation. The resulting ordinary differential equations for the scaling parameters are then solved numerically for experimentally realistic parameters for increasing relaxation times. Our analysis is, thus, useful for future TOF experiments in order to determine the value of the underlying relaxation time from expansion data.

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

Q 15.41 Mon 17:00 C/Foyer

Bogoliubov Theory of Dipolar Bose Gas in Weak Random Potential — •Mahmoud Ghabour[1] and Axel Pelster[2] — [1]Physics Department, Freie Universität Berlin, Germany — [2]Physics Department and Research Center OPTIMAS, Technische Universität Kaiserslautern, Germany

We consider a dilute homogeneous Bose gas with both an isotropic short-range contact interaction and an anisotropic long-range dipole-dipole interaction in a weak random potential at low temperature in three dimensions. Within the realm of Bogoliubov theory we analyze how both condensate and superfluid density are depleted due to quantum and thermal fluctuations as well as disorder fluctuations. Afterwards, we calculate with this the resulting velocities of first and second sound within an anisotropic extension of the Landau-Khalatinikov two-fluid model.

[1] K. Huang and H. F. Meng, Phys. Rev. Lett. **69**, 644 (1992)
[2] C. Krumnow and A. Pelster, Phys. Rev. A **84**, 021608(R) (2011)
[3] B. Nikolic, A. Balaz, and A. Pelster, Phys. Rev. A **88**, 013624 (2013)
[4] M. Ghabour and A. Pelster, `arXiv:1410.3070`

Q 15.42 Mon 17:00 C/Foyer

Analytical and Numerical Study of Bose-Einstein Condensate with Localized Impurity — •Javed Akram[1] and Axel Pelster[2] — [1]Physics Department, Freie Universität Berlin Germany — [2]Physics Department and Research Center OPTIMAS, Technische Universität Kaiserslautern Germany

Motivated by the recent experimental work of Refs. [1, 2], we investigate a localized ^{133}Cs impurity in the center of a trapped ^{87}Rb

Bose-Einstein condensate. Within a zero-temperature Gross-Pitaevskii mean-field description we provide a one-dimensional physically intuitive model, which we solve by both a time-independent variational approach and numerical calculations. With this we predict at first equilibrium results for the emerging condensate wave function which reveals an impurity-induced dip or bump in case of a repulsive or an attractive Rb-Cs interaction strength. Afterwards, we show that the impurity-induced dip or bump in the condensate wave function remains even present during a time-of-flight (TOF) expansion after having switched off the harmonic confinement. All these results are useful for extracting the Rb-Cs interaction strength from experimental TOF expansion data.

[1] A.D. Lercher, T. Takekoshi, M. Debatin, B. Schuster, R. Rameshan, F. Ferlaino, R. Grimm, and H.-C. Nägerl, Euro. Phys. J. D **65**, 3 (2011).

[2] N. Spethmann, F. Kindermann, S. John, C. Weber, D. Meschede, and A. Widera, Phys. Rev. Lett. **109**, 235301 (2012).

Q 15.43 Mon 17:00 C/Foyer

One-Dimensional Model for Bose-Einstein Condensate in Gravito-Optical Surface Trap — •Javed Akram[1], Benjamin Girodias[2], and Axel Pelster[3] — [1]Department of Physics, Freie Universität Berlin, Germany — [2]Pomona College, Claremont, USA — [3]Physics Department and Research Center OPTIMAS, Technische Universität Kaiserslautern, Germany

We study both static and dynamic properties of a weakly interacting Bose-Einstein condensate in a quasi-one-dimensional gravito-optical trap, where the downward pull of gravity is compensated by the exponentially decaying potential of an evanescent wave. At first we work out approximate solutions to the Gross-Pitaevskii equation for small number of atoms using a variational Gaussian ansatz and for larger number of atoms using the Thomas-Fermi limit. Then we confirm the accuracy of these approximate analytic solutions by comparing them to numerical results. From there, we numerically analyze how the BEC cloud expands ballistically when the confining laser beams are shut off, showing agreement between our theoretical and previous experimental results.

Q 15.44 Mon 17:00 C/Foyer

Anyons in 1D optical lattices by time periodic forcing — •Christoph Sträter[1], Shashi Srivastava[1], Marco Roncaglia[2], Axel Pelster[3], and André Eckardt[1] — [1]Max Planck Institute for the Physics of Complex Systems, Dresden, Germany — [2]Istituto nazionale di ricerca metrologica, Turin, Italy — [3]Kaiserslautern University of Technology, Kaiserslautern, Germany

Anyons are particles that pick up a complex phase factor upon particle exchange. In one dimensional optical lattices, it has been proposed to create anyons by engineering occupation-dependent tunneling amplitudes for bosonic atoms by means of Raman assisted tunneling [1]. We propose a different scheme for the realization of such 1D anyons that relies on lattice shaking. Our scheme is very easy to implement experimentally, since it neither relies on the internal atomic structure nor requires additional lasers.

Q 15.45 Mon 17:00 C/Foyer

Stationary and Transient Properties of Photon Condensates — •Milan Radonjić[1], Antun Balaž[2], Wassilij Kopylov[3], Tobias Brandes[3], and Axel Pelster[4] — [1]Photonics Center, Institute of Physics Belgrade, University of Belgrade, Serbia — [2]Scientific Computing Laboratory, Institute of Physics Belgrade, University of Belgrade, Serbia — [3]Institute for Theoretical Physics, Technische Univesität Berlin, Germany — [4]Physics Department and Research Center OPTIMAS, Technische Universität Kaiserslautern, Germany

A seminal experiment in Bonn has presented convincing evidence of both a Bose-Einstein distribution and a macroscopic occupation of the lowest mode for a gas of photons confined in a dye-filled optical microcavity. Here we investigate how these equilibrium properties could be understood within the framework of a recent non-equilibrium model of photons in terms of a steady state solution. It turns out that, depending on the dye pumping rate and the cavity decay rate, different modes become macroscopically occupied. We present the corresponding phase diagrams and describe the transitions between the phases analytically. Furthermore, we obtain a moment generating function for the photon statistics and calculate the stationary equal-time autocorrelation function. Using a linear stability analysis we demonstrate that the stationary states are always unconditionally stable. We also examine how the relaxation times toward equilibrium depend on the respective system parameters and compare them with the thermalization times obtained experimentally from the corresponding transient dynamics.

Q 15.46 Mon 17:00 C/Foyer

Towards the Realization of a Vacuum-Ultraviolet Photon Bose-Einstein Condensate — •Christian Wahl, Gunar Wallstabe, Stavros Christopoulos, Jan Klaers, and Martin Weitz — University of Bonn, Germany

We propose a new approach for photon Bose-Einstein condensation, based on thermalisation of photons in a noble gas filled optical microcavity, suitable for the vacuum-ultraviolet spectral regime, i.e. in the 100-200nm wavelength regime. While current experiments on photon Bose-Einstein condensation use thermalisation of photons in a dye solution filled optical microcavity in the visible spectral regime [1], we here plan to use absorption re-emission cycles of the transition from the ground to the the lowest electronically excited state of e.g. xenon for thermalisation. In order to achieve a sufficient overlap between the first atomic absorption and the di-atomic excimer emission, found at 147nm and 170nm respectively [2], a noble gas pressure of up to 60 bar will be created inside the cavity. We are currently in the process of setting up an experiment to study absorption and emission spectra at the relevant noble gas pressures in the vacuum-ultraviolet regime. Ongoing experimental progress will be reported.

References:

[1]: J. Klaers et al. Nature **468**, 545-548 (2010)

[2]: M. Kink et al. Physica Scripta **45**, 79-82 (1992)

Q 15.47 Mon 17:00 C/Foyer

Measuring the Chern number of Hofstadter bands with ultracold bosonic atoms — •Christian Schweizer[1,2], Monika Aidelsburger[1,2], Michael Lohse[1,2], Marcos Atala[1,2], Julio Barreiro[1,2], Sylvain Nascimbène[3], Nigel Cooper[4], Immanuel Bloch[1,2], and Nathan Goldman[3,5] — [1]Fakultät für Physik, LMU München, Germany — [2]MPQ Garching, Germany — [3]Collège de France & LKB, CNRS, UPMC, ENS, Paris, France — [4]T.C.M. Group, Cavendish Laboratory, Cambridge, UK — [5]CENOLI, Faculté des Sciences, Université Libre de Bruxelles, Belgium

Sixty years ago, Karplus and Luttinger pointed out that quantum particles moving on a lattice could acquire an anomalous transverse velocity in response to a force, providing an explanation for the unusual Hall effect in ferromagnetic metals. A striking manifestation of this transverse transport was then revealed in the quantum Hall effect, where the plateaus depicted by the Hall conductivity were attributed to a topological invariant characterizing Bloch bands: the Chern number. Until now, topological transport associated with non-zero Chern numbers has only been revealed in electronic systems. Here we use studies of an atomic cloud's transverse deflection in response to an optical gradient, in combination with the determination of the band populations to measure the Chern number ν of artificially generated Hofstadter bands; for the lowest band we obtain an experimental value of $\nu_{\text{exp}} = 0.99(5)$. This result, which constitutes the first Chern-number measurement in an atomic system, is facilitated by an all-optical artificial gauge field scheme, generating uniform flux in optical superlattices.

Q 15.48 Mon 17:00 C/Foyer

Towards many body physics with ultracold atoms in optical microtrap arrays — •Martin Sturm, Malte Schlosser, Gerhard Birkl, and Reinhold Walser — Institut für Angewandte Physik, TU Darmstadt

Ultracold atoms in optical lattices have proven to be a powerful toolbox for quantum simulation of many body physics e.g., solid state systems. Standard optical lattices are produced by the superposition of standing wave laser fields and have been used for simulating large homogeneous lattice systems. In recent years single-site addressability in optical lattices has attracted considerable interest since it allows for the direct observation and control of local properties.

We propose an experimental scheme to implement quantum simulation of many body systems using ultracold Rubidium atoms in optical dipole traps generated by microlens arrays. This allows to produce 1D and 2D optical lattices for which the task of single site control can be implemented by selectively addressing each microlens. This setup has already been used for quantum computation experiments [1]. We set the superfluid-insulator phase transition of the Bose-Hubbard model as a benchmark to demonstrate the accessibility of relevant many body regimes with this setup. We further investigate new possibilities that arise with the tunable shape and size of the system e.g., systematic investigation of finite size effects and quantum transport.

[1] M. Schlosser et al., Quantum Inform. Process. **10** 907-924

Q 15.49 Mon 17:00 C/Foyer

Integration of photonic structures and thermal atomic vapors — •Ralf Ritter[1], Nico Gruhler[2], Wolfram Pernice[2], Tilman Pfau[1], and Robert Löw[1] — [1]5. Physikalisches Institut, Universität Stuttgart — [2]Institute of Nanotechnology, KIT Karlsruhe

The usage of atomic vapors in technological applications has become increasingly relevant over the past few years. They are utilized e.g. in atomic clocks, magnetometers, as frequency reference or to slow down and store light. Integrated devices, which combine photonic structures and thermal atomic vapors on a chip, could be an ideal basis for such purposes, as they provide efficient atom-light coupling on a miniaturized scale.

We will report on the status of our work on various photonic structures such as dielectric waveguides, directional couplers and interferometers combined with thermal alkali vapor.

Q 15.50 Mon 17:00 C/Foyer

Cold Atom Based Magnetic Microscopy — •Timothy James[1], Amruta Gadge[1], Jorge Ferras[1], Jessica Maclean[1], Christopher Mellor[1], Francesco Intravaia[2], Mark Fromhold[1], Christian Koller[3], Fedja Orucevic[1], and Peter Kruger[1] — [1]School of physics and Astronomy, University of Nottingham, Nottingham NG7 2RD — [2]Institut fur Physik, Humboldt- Universitaet zu Berlin, Newtonstr. 15, 12489 Berlin, Germany. — [3]Mirco- & Nano systems FH Wiener Neustadt, Austria

Cold atoms can be used as highly sensitive surface probes. The resolution of the probes would be increased by trapping the atoms closer to the surface. However closer trapping to the surface leads to higher loss rates due to distance based effects such as Johnson noise and Casimir force.

The use of a dual colour magneto optical trap will allow for the trapping of an increased number of atoms than is achieved using the single MOT. We will present a simple model for the interaction of an atom with the two mode light field.

We are designing a PCB to allow the transport of atoms from MOT to the surface of a sample. The samples will be composed of graphene sheets supported by a TEM grid and graphene hall bars.

Q 15.51 Mon 17:00 C/Foyer

Integrated atom traps for quantum sensor applications — •Jorge Ferreras, Thomas Barrett, Anton Piccardo-Selg, Jessica Maclean, Christopher Mellor, Thomas Fernholz, Fedja Orucevic, and Peter Kruger — School of Physics and Astronomy, The University of Nottingham, UK

Trapping and cooling atoms close to surfaces broadens the horizon on quantum sensor applications. However, size has always been a constraint for making such devices. With new understructures and multi-layers chips, it is now possible to miniaturize this setups. A compact low-power consumption system can be used to routinely trap and cool atoms down to and below temperatures at which Bose-Einstein Condensation (BEC) occurs. We demonstrate how self-contained integrated structures are used to produce Rb BECs with power dissipation in the milliwatt range. Truly portable sensors based on ultracold gases are now being developed with a view to a wide range of industrial applications, including underground mapping and navigation.

Q 15.52 Mon 17:00 C/Foyer

Aspects of Analogue Gravity with Bose-Einstein Condensates — •Andreas Finke[1,2], Silke Weinfurtner[2], and Peter Kruger[1] — [1]School of Physics and Astronomy, The University of Nottingham, UK — [2]School of Mathematical Sciences, The University of Nottingham

Phononic excitations in an engineered Bose-Einstein condensate (BEC) are one example out of a larger class of physical systems admitting a description very similar to certain models of quantum fields in curved spacetimes. We argue that the large degree of control offered by an atom chip makes it possible to investigate questions about universality and stability of effects analogue to e.g. cosmological particle production or Hawking radiation in a BEC. To increase experimental signatures one is naturally led to the study of non-equilibrium behaviour and corrections from (strong) interactions. We further investigate a way to increase the signature of quantum fluctuations at given background temperature and report on the status of our experiments.

Q 15.53 Mon 17:00 C/Foyer

Non-equilibrium mass transport in bosonic quantum systems — •Christian Baals, Bodhaditya Santra, Ralf Labouvie, Simon Heun, and Herwig Ott — Research Center OPTIMAS and Fachbereich Physik, Technische Universität Kaiserslautern, 67663 Kaiserslautern, Germany

We study the dynamics of a Bose-Einstein condensate (BEC) after a quench of the density distribution. To this purpose, we use a tightly focused electron beam which is implemented in a standard BEC apparatus. The electron beam serves as a detection device where the atoms are ionized by electron-impact, extracted from the atomic cloud and detected. Additionally, the electron beam allows us to tailor the atomic density distribution and to locally apply losses as a source of dissipation. Our aim is to investigate the dynamics of such an out-of-equilibrium situation. In a first experiment, we shine the electron beam on an atomic BEC and measure the losses as a function of the dissipation strength. Above a critical limit, we observe the appearance of quantum Zeno dynamics. A similar situation can be created when the BEC is loaded into a one-dimensional optical lattice and a lattice site is continuously probed by the electron beam. Initially removing atoms from one lattice site and observing the ensuing refilling dynamics, makes it possible to measure the conductivity of the system. We find that the interplay between the interaction energy, the tunneling coupling and intrinsic collisions leads to negative differential conductivity.

Q 15.54 Mon 17:00 C/Foyer

Local study of quantum transport close to and far away from equilibrium — •Jae-Yoon Choi[1], Sebastian Hild[1], Takeshi Fukuhara[1], Peter Schauss[1], Johannes Zeiher[1], Immanuel Bloch[1,2], and Christian Gross[1] — [1]Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Straße 1, 85748 Garching, Germany — [2]Fakultät für Physik, Ludwig-Maximilians-Universität München, Schellingstraße 4, 80799 München, Germany

Ultracold atom experiments are well suitable to study out-of-equilibrium dynamics of quantum many-boy systems. A well controlled locally excited atomic Mott insulator state serves as initial state to study the dynamics in different regimes of the Bose-Hubbard model. The ability to manipulate and detect atoms on the single site level opens up novel experimental possibilities to study the dynamics. We report on transport measurements far away from equilibrium where we observe diffusively decaying spin spirals. In contrast, when studying the dynamics close to equilibrium using single impurities we find ballistic transport that is linked to bipartite entanglement generation between different sites.

Q 15.55 Mon 17:00 C/Foyer

Many-Body Localization in Quasi-Random and Superlattice Geometries — •Henrik Lüschen[1,2], Michael Schreiber[1,2], Pranjal Bordia[1,2], Sean Hodgman[1,2], Immanuel Bloch[1,2], and Ulrich Schneider[1,2] — [1]Max-Planck-Institut für Quantenoptik, Garching — [2]Ludwig-Maximilians-Universität, München

Disordered systems have been the subject of great interest over the last few years, especially in the context of many-body localization (MBL) of interacting systems. So far, experimental studies have been using transport properties as observables and were mostly limited to the bosonic case. We have implemented a new setup that enables us to directly observe the breakdown of ergodicity and thermalization in the fermionic Aubrey-André model by monitoring local observables after a quantum quench.

Specifically, we use a superlattice to create an initial charge-density wave and measure the population imbalance between even and odd sites. While this imbalance quickly relaxes to zero in the clean system without disorder, at sufficiently strong quasi-disorder we observe a large remaining imbalance in the long term limit, indicating MBL. The imbalance hence directly demonstrates the absence of thermalization and can be used as an effective order parameter for MBL transitions.

Furthermore, we give an outlook on possible future experiments, elaborating on the possibilities of coupling a localized system to a phonon bath, as well as accessing spin degrees of freedom with our superlattice, e.g. observing singlet-triplet oscillations and creating spinordered states.

Q 15.56 Mon 17:00 C/Foyer

A state dependent lattice for many body physics with yt-

terbium — •Luis Riegger[1,2], Christian Hofrichter[1,2], Moritz Höfer[1,2], Francesco Scazza[1,2], Diogo Rio Fernandes[1,2], Immanuel Bloch[1,2], and Simon Fölling[1,2] — [1]Ludwig-Maximilians-Universität, München, Deutschland — [2]Max-Planck-Institut für Quantenoptik, Garching, Deutschland

In contrast to the more common alkali atoms, ytterbium possesses a metastable excited state as well as a strong decoupling between the nuclear and the electronic spin degree of freedom.

We report on the realization of a state dependent lattice for the $^1S_0$ ground and $^3P_0$ meta-stable state of ytterbium. Since the state dependence arises from the different AC-polarizability of the two electronic configurations, the optical lattice remains nuclear spin independent. This degree of freedom is an important ingredient for the simulation of many-body systems such as Kondo physics.

Imposing such a "non-magic" lattice on a degenerate quantum gas of either bosonic or fermionic ytterbium isotopes, we are able to prepare specific lattice Hamiltonians, which we probe spectroscopically and dynamically.

Q 15.57 Mon 17:00 C/Foyer

Probing Bloch band geometry and topology with ultracold atoms — •Martin Reitter[1,2], Lucia Duca[1,2], Tracy Li[1,2], Sebastian Scherg[1,2], Immanuel Bloch[1,2], Monika Schleier-Smith[3], and Ulrich Schneider[1,2] — [1]Ludwig-Maximilians-Universität, München, DE — [2]MPQ, Garching, DE — [3]Stanford University, Palo Alto, USA

Topological features lie at the heart of a wide range of many-body phenomena in solid state systems. We have experimentally studied local topological properties of a graphene-like optical lattice, which features two nonequivalent Dirac points in the first Brillouin zone. By performing Ramsey interferometry along closed loops around one of the Dirac points, we are able to directly measure a Berry phase of π and locate the Berry curvature with high momentum resolution. In addition, we will report on the first measurements of multiband topological properties in the presence of a strong gradient. In this regime, the two lowest bands are formally equivalent to the case of two degenerate bands, as described by Wilczek and Zee [1]. By combining Stückelberg interferometry and measurements of the population transfer to the second band, we are able to reconstruct the elements of the Wilson loop matrix that characterizes this two-band model. Future research directions are also presented.

[1]F. Wilczek and A. Zee., Phys. Rev. Lett. 52, 2111 (1984).

Q 15.58 Mon 17:00 C/Foyer

Optical bloch band spectroscopy of the $^1S_0$ - $^3P_0$ transition of laser cooled magnesium atoms — •Klaus Zipfel, André Kulosa, Steffen Rühmann, Dominika Fim, Nandan Jha, Steffen Sauer, Wolfgang Ertmer, and Ernst Rasel — Institut für Quantenoptik, Leibniz Universität Hannover, 30167 Hannover, Germany

Optical atomic clocks perform spectroscopy on narrow transitions of atoms trapped in an optical lattice operated at the "magic wavelength". As in solid-state physics, such periodic optical potentials give rise to band structures caused by tunnelling of the delocalized atoms and thus can be used to simulate pure crystalline structures. By operating the lattice in a regime where the tunnelling rate becomes comparable to the observable linewidth of the narrow transition, the band structure can be observed in the frequency spectrum. We present the direct observation of bloch bands by probing the spin-forbidden $^1S_0$ - $^3P_0$ transition of laser cooled magnesium atoms trapped in an optical lattice operated at the magic wavelength. For trap depths of 10 recoil energies the band width is around 3 kHz which corresponds to the current resolution of the probed transition. In this regime a shift resulting in a symmetric splitting to a doublet structure in the order of the band width has been observed.

Q 15.59 Mon 17:00 C/Foyer

Dual Species matter-wave Interferometry — •Hendrik Heine, Henning Albers, Jonas Hartwig, Dipankar Nath, Logan Richardson, Dennis Schlippert, Wolfgang Ertmer, and Ernst M. Rasel — Institut für Quantenoptik, Leibniz Universität Hannover, Welfengarten 1, 30167 Hannover

One of the cornerstones in Einstein's General Relativity is the Universality of Free Fall (UFF) which has been examined in many classical experiments. We present a Quantum Test of the UFF based on a two species Raman-type matter-wave interferometer operating with thermal clouds of ^{87}Rb and ^{39}K to differentially measure the gravitationally-induced phase shift.

Both species are simultaneously trapped in a three-dimensional magneto-optical trap (MOT) which is loaded by a 2D-MOT. After cooling ^{87}Rb (^{39}K) to 27 μK (32 μK) they are released into free fall. While falling, the interferometer sequence is applied with two pairs of counter-propagating Raman-beams splitting, redirecting and recombining the atomic ensembles with a typical pulse separation time of $T = 20\,\text{ms}$. By inverting the orientation of the interferometer, we can suppress the most important Bias contributions of non-inertial phase-shifts in the half-difference of the signals.

We present a measurement of the Eötvös-ratio up to a level of $\eta_{\text{Rb,K}} = (0,3 \pm 5,4) * 10^{-7}$ and show the potential for future improvements of the measurement.

Q 15.60 Mon 17:00 C/Foyer

Matter wave interferometry in space — •Maike Diana Lachmann, Stephan Tobias Seidel, Dennis Becker, Jung-Bin Wang, Thijs Wendrichs, Wolfgang Ertmer, and Ernst Maria Rasel for the QUANTUS-Collaboration — Institut für Quantenoptik, LU Hannover

Extending the free-fall time in atom interferometers is one approach towards a precise measurement of the equivalence principle. Therefore experiments with ultra-cold quantum gases in microgravity have been realized and performed at the drop tower facility in Bremen, Germany. As a next step space missions have a high potential for measurements in microgravity. With the sounding rocket mission MAIUS the first creation if a BEC in space and the demonstration of atom interferometry is planed. This poster shows the setup, the performance of the apparatus on the ground and future prospects of the project.

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 number DLR 50 1131 - 1137.

Q 15.61 Mon 17:00 C/Foyer

Very Long Baseline Atom Interferometry for High-Accuracy Gravimetry and Tests of Fundamental Physics — •Étienne Wodey, Christian Meiners, Jonas Hartwig, Dennis Schlippert, Christian Schubert, Wolfgang Ertmer, and Ernst M. Rasel — Institut für Quantenoptik, Leibniz Universität Hannover

Very Long Baseline Atom Interferometry (VLBAI) represents a new class of experiments in atom optics with applications in high-accuracy absolute gravimetry, gradiometry and tests of fundamental physics. Extending the baseline of gravimeters from tens of centimeters to several meters opens the way for competition with superconducting gravimeters and quantum tests of the universality of free fall (UFF) at an unprecedented level, comparable to those achieved by classical lunar laser ranging and torsion balance tests. Also, the implementation of a gradiometer in the vertical direction will complement the research effort done by the MIGA collaboration towards 3D gravity antennas and mapping of space-time strain in the low-frequency range. The VLBAI-Teststand will consist of a 10m-baseline atom interferometer implemented in the Hannover Institut für Technologie (HITec) of the LUH. For UFF tests, it will be operated as a simultaneous gravimeter using ultracold mixtures of ytterbium and rubidium atoms. The choice of ytterbium is motivated by its high mass and the very small sensitivity of the ground states of the bosonic isotopes to magnetic fields, enabling better control of the systematics and constraining violation parameters. In this poster, we present an overview of the design of the apparatus and the status of our source of cold ytterbium atoms.

Q 15.62 Mon 17:00 C/Foyer

Lamb-Dicke spectroscopy of the $^1S_0 \to {}^3P_0$ clock transition in bosonic magnesium — •Nandan Jha, André Kulosa, Steffen Rühmann, Dominika Fim, Klaus Zipfel, Steffen Sauer, Wolfgang Ertmer, and Ernst Rasel — Institut für Quantenoptik, Leibniz Universität Hannover, Deutschland

We report on a measurement of the magic wavelength of bosonic ^{24}Mg. At this particular wavelength the differential AC-Stark shift between the clock states vanishes.

The experimental cycle for loading the optical lattice is as follows: 10^9 atoms are pre-cooled in two magneto-optical traps (singlet-MOT at 285 nm and triplet-MOT at 383 nm) and continuously loaded in an optical dipole trap at 1064 nm. 10^4 Atoms are then transferred to the optical lattice at 469 nm. In order to generate sufficient power for trapping of magnesium, the incident power of 90 mW is enhanced to 2 W in a build-up cavity.

An external homogeneous magnetic field gives a small admixture of the $^3P_1$ state to the $^3P_0$ state allowing direct excitation of the strongly forbidden $^1S_0 \rightarrow {}^3P_0$ clock transition. From the spectroscopy signal we observe a clear asymmetry between the red and the blue sideband of the carrier, which infers that most of the atoms are in the vibrational ground state of the trap. Their temperature evaluates to 7 μK. We varied the lattice power at different wavelengths for measuring the differential AC-Stark shifts of the carrier transition. The magic wavelength of ^{24}Mg results to 468.44(17) nm.

Q 15.63 Mon 17:00 C/Foyer

Progress Report Towards an Al+ Quantum Logic Optical Clock — •Stephan Hannig[1], Nils Scharnhorst[1], Jannes B. Wübbena[1], Kornelius Jakobsen[1], Ian D. Leroux[1], and Piet O. Schmidt[1,2] — [1]QUEST Institute for Experimental Quantum Metrology, PTB, 38116 Braunschweig, Germany — [2]LUH, 30167 Hannover, Germany

We present the status of our aluminium ion optical clock using quantum logic techniques for cooling and reading out the clock ion. The design goals for the frequency standard are an inaccuracy below 10^{-17} and relative instability better than 10^{-15} in one second. ^{27}Al$^+$ provides a narrow (8 mHz) clock transition at 267 nm which exhibits no electric quadrupole shift and a low sensitivity to black-body radiation. A single ^{27}Al$^+$ ion will be confined in a linear Paul Trap together with a ^{40}Ca$^+$ logic ion. The latter is used for sympathetic cooling and internal state detection of the clock ion via Coulomb interaction.

We show a setup to transfer the stability of an ultra-stable reference laser to the 729 nm Ca$^+$ logic laser. Additionally, the status of the experiment and recent results including double EIT cooling are presented.

Recently, a second generation, new vacuum chamber has been set up. The new system is designed to include a segmented multi-layer linear Paul trap. It paves the way towards multi-ion clocks, combining the high accuracy of single-ion clocks with high stability.

Q 15.64 Mon 17:00 C/Foyer

Progress Report of an ultra-stable cavity for an Al+ optical clock — Sana Amairi Pyka[1], •Kornelius Jakobsen[1], Nils Scharnhorst[1], Stephan Hannig[1], Ian D. Leroux[1], and Piet O. Schmidt[1,2] — [1]QUEST Institute, Physikalisch Technische Bundesanstalt, 38116 Braunschweig, Germany — [2]Institut für Quantenoptik, Leibnitz-Universität Hannover, 30167 Hannover, Germany

We present the current status of the reference cavity for the clock laser of our aluminium ion frequency standard. A 1070 nm laser is stabilized to a 39.5 cm long cavity made of ultra-low expansion glass and is thereafter frequency-doubled twice to achieve the transition wavelength of 267 nm. The cavity has an estimated thermal noise limit of $7 \cdot 10^{-17}$ in 1 s. Despite its length, the system exhibits a very low sensitivity to vibrations of less than 10^{-11}/m s^{-2} in all three directions. We present an evaluation of possible performance-limiting effects, such as residual amplitude noise and intensity stability of the laser light inside the cavity. These results are complemented by a comparison with other clock cavities at PTB. The evaluation shows that such long cavities are suitable for sub-Hertz spectroscopy at optical frequencies.

Q 15.65 Mon 17:00 C/Foyer

Towards a cryo-lattice clock at PTB — •Ali Al-Masoudi, Sören Dörscher, Stephan Falke, Sebastian Häfner, Stefan Vogt, Uwe Sterr, and Christian Lisdat — Physikalisch-Technische Bundesanstalt (PTB), Bundesallee 100, 38116 Braunschweig

Optical clocks have become valuable tools for frequency metrology with applications ranging from the search for physics beyond the standard model to relativistic geodesy. Strontium lattice clocks offer high stabilities, but their best uncertainty budgets have been dominated by the Stark shift due to black-body radiation. With the atomic sensitivity itself well known from our previous measurements, knowledge and control of the thermal environment have been the limiting factor. Several groups have recently demonstrated approaches to overcome this limitation and reached relative uncertainties as low as 5×10^{-18}. We report on the integration of a thermally well-controlled, cryogenic environment into our existing setup. We expect to achieve a total relative uncertainty of 1×10^{-17}, limited by constraints of our optical lattice geometry. Finally, we present the recent progress of a new physics package for a next-generation ^{87}Sr clock aiming at uncertainties of 1×10^{-18} and better. It is designed to allow detailed investigations of further points of concern, e.g. higher-order contributions to the lattice light shifts. This work is supported by QUEST, the DFG within CRC 1128 (geo-Q) and RTG 1729, and the EMRP within IND14, ITOC, and QESOCAS. The EMRP is jointly funded by the EMRP-participating countries within EURAMET and the European Union.

Q 15.66 Mon 17:00 C/Foyer

Spectroscopy of the clock transition in ^{171}Yb in a transportable setup — •Gregor Mura, Tobias Franzen, Axel Görlitz, Heiko Luckmann, Alexander Nevsky, Ingo Ernsting, and Stephan Schiller — Institut für Experimentalphysik, HHU Düsseldorf, Universitätsstr. 1, 40225 Düsseldorf

Optical lattice clocks based on elements with two valence electrons are strong competitors in the quest for next generation time and frequency standard. While promising results have already been obtained on several stationary setups using Sr and Yb, transportable clocks are desirable for both performance evaluation and applications.

In the framework of the Space Optical Clocks 2 project, we are developing a transportable Yb lattice clock demonstrator. Our setup is based on diode and fiber lasers and features an intra-vacuum enhancement resonator to allow the formation of a large volume lattice using moderate laser power.

Here we present our recent results of the spectroscopy of the $^1S_0 \rightarrow {}^3P_0$ transition in ^{171}Yb confined in an one dimensional optical lattice, a first evaluation of systematics and ongoing work towards competitive clock operation as well as more compact and robust subsystems.

Q 15.67 Mon 17:00 C/Foyer

A closed-cycle cryostat setup for next-generation optical resonators with ultra-high frequency stability — •Christian Marciniak, Moritz Nagel, Klaus Döringshoff, Sylvia Schikora, Evgeny V. Kovalchuk, and Achim Peters — Humboldt-Universität zu Berlin, Institut für Physik, AG Optische Metrologie, Newtonstraße 15, 12489 Berlin

We present the current state of our work on design and setup of a novel closed-cycled cryostat system for sapphire optical resonators. The system will operate at liquid helium temperatures and will provide an ultra-low vibration environment for the cavities. The presentation will include details of mechanical design, supporting room-temperature optics as well as considerations into cryogenic optical design such as stray interference minimization and ghosting.

The expected performance of the sapphire resonators is thermal noise limited in frequency stability at 10^{-17} which will be used for the next generation of Michelson-Morley experiments to test Lorentz invariance at the 10^{-20} regime.

Q 15.68 Mon 17:00 C/Foyer

Ein optischer Resonator im Fallturmbetrieb — •Andreas Resch, Sven Herrmann und Claus Lämmerzahl — ZARM Universität Bremen, Am Fallturm, 28359 Bremen, GERMANY

Hochstabile Laser(-system) werden in vielen Präzisionsexperimenten eingesetzt. Die technische Entwicklung zeigt den Weg hin zur Weltraumanwendung dieser Lasersysteme. Ein erster Schritt kann in einem Experiment im Fallturm unter Mikrogravitation stattfinden.

Wir präsentieren die Entwicklung und die Realisierung eines Fallturmaufbaus, der zum ersten Mal einen optischen Resonator im Fallturmbetrieb zulässt.

Zum Einsatz kommt ein sphärischer Abstandshalter aus ULE mit fused silica Spiegeln von denen ein Spiegel plan und der zweite konvex ist. Der Resonator wird mit acht Stützen in seiner Lage fixiert, bei dem durch Einhaltung des magischen Winkels eine hohe Vibrationsunterdrückung erreicht wird.

Die präsentierten Ziele sind zunächst einen aktiven Betrieb sicher zu stellen und im Fallturm die Linienbreite zu bestimmen. Die Ergebnisse werden hier präsentiert.

Q 15.69 Mon 17:00 C/Foyer

Long-term stable optical resonator for future space missions — •Alexander Milke[1,2], Norman Gürlebeck[2], Josep Sanjuán[1], Martin Gohlke[1], Thilo Schuldt[1], and Claus Braxmaier[1,2] — [1]German Aerospace Center (DLR), Institute for Space Systems, Robert-Hooke-Str. 7, 28359 Bremen, Germany — [2]Center of Applied Space Technology and Microgravity (ZARM), University of Bremen, Am Fallturm, 28359 Bremen, Germany

We present the design of an optical resonator setup, which is optimized for long-term stability and future space applications, e.g. within the proposed space mission BOOST (BOOst Symmetry Test). The goal is to achieve a frequency stability better than 1E-15 at 1000 s in the laboratory. In the setup a ND:YAG laser at 1064 nm is foreseen to be stabilized on a high finesse cavity made of ULE (ultra low expansion glass) and fused silica mirrors. The whole setup is optimized with respect to its mass, compactness, thermal and vibrational robustness. We are also focusing on the suppression of thermal environmental disturbances using a thermal shielding attenuation. The shielding has been developed with the help of highly accurate numerical simulations using finite element analysis (FEA). Such highly stable and compact frequency standards are crucial for space tests of fundamental physics like tests of Lorentz Invariance.

Q 15.70 Mon 17:00 C/Foyer

High-precision Mid-IR wavelength meters — •Milán János Negyedi[1], Florian Karlewski[2], Thomas Fischer[1], and József Fortágh[2] — [1]HighFinesse GmbH, Auf der Morgenstelle 14D 72076 Tübingen — [2]Universität Tübingen Physikalische Institut Auf der Morgenstelle 14D 72076 Tübingen

With the increasing attention on cold molecular physics, the need for extremely precise Mid-IR wavelength meters is growing. Since the current state-of-the-art instruments are lacking in either accuracy or sampling speed, further research is needed to meet the requirements. We summarize the present state of technology and present our developments towards a Doppler-level accurate wavemeter with over 100 Hz sampling rate.

Q 15.71 Mon 17:00 C/Foyer

Length Sensing and Control of Einstein Telescope-Low Frequency — •Vaishali Adya[1] and Sean Leavey[2] — [1]Max Planck institute for Gravitational Physics, AEI, Hannover, Germany — [2]University of Glasgow,Glasgow,Scotland

It is important to be able to control the positions of the mirrors in the interferometer in order to maintain maximum sensitivity to gravitational waves.We describe the development of a feasible length sensing and control scheme for the Einstein telescope operating in the low frequency regime which has a dual recycled Michelson topology with Fabry-Perot arm cavities. A preliminary DC sensing matrix has been obtained using models built with two interferometer simulation packages (Optickle and FINESSE) . We also worked on the optimisation of several optical parameters such as the length of the recycling cavities and the modulation frequencies, the details of which are also described in the talk.

Q 15.72 Mon 17:00 C/Foyer

Kontrolle von Antimaterieionen zur Bestimmung der Wirkung der Gravitation auf Antimaterie — •Sebastian Wolf, Merle Braun und Ferdinand Schmidt-Kaler — QUANTUM, Institut für Physik, Johannes Gutenberg-Universität Mainz

Die Materie/Antimaterie-Symmetrie ist eines der drängensten Themen der Physik. Experimentell weitgehend unbestimmt ist die gravitative Wechselwirkung zwischen Materie und Antimaterie [1].

Die GBAR-Kollaboration [2,3] plant positiv geladene Antiwasserstoffionen ($\bar{p}^- + 2e^+$) am CERN zu erzeugen. Diese werden in einer Paulfalle gefangen und mitfühlend über lasergekühlte Beryllium-Ionen nahe an den Grundzustand der Bewegung gekühlt [4]. Nach Abtrennen eines Positrons entsteht ultrakalter Anti-Wasserstoff der eine Messung der Erdbeschleunigung erlaubt. Wir präsentieren den Ionenfallenaufbau und berichten über Seitenbandspektroskopie/-kühlung an gemischten Ionenkristallen.

Der dominante systematische Fehler bei der Messung von $\bar{g}$ ist bedingt durch die Resttemperatur der Ionen und den Impulsübertrag des Positrons. Wir haben in Simulationen gezeigt, dass durch Zuhilfenahme der radialen Position des Zerstrahlungsvertex die Beschleunigungsbestimmung besser als 1% innerhalb von 11000 Messereignissen (entsprechend einer Messzeit von 14 Tagen) möglich ist.

[1] The ALPHA Collaboration, Nat. Comm., 4, 1785 (2013).
[2] http://gbar.web.cern.ch/GBAR/
[3] Walz and Hänsch, Gen. Relativ. Grav., 36, 561-570 (2004).
[4] Hilico et al, Int. J. Mod. Phys. Conf. Ser., 30, 1460269 (2014).

Q 15.73 Mon 17:00 C/Foyer

Laser Frequency Stabilisation for the AEI 10 m Prototype Interferometer — •Manuela Hanke — Albert-Einstein-Institut Hannover

The 10 m Prototype facility, currently being set up at the AEI Hannover, will provide a testbed for very sensitive interferometric experiments. One ambitious goal of this project is to reach and subsequently even surpass the standard quantum limit in a detection band around 200 Hz with a 10 m arm length Michelson interferometer. In order to pursue such an avenue, the laser source must be extremely well stabilised. The laser source was chosen to be one of the 35 W lasers used to drive the km-scale gravitational wave observatories, LIGO and GEO 600. A fully suspended triangular ring cavity of finesse ca. 3000 will be used as a frequency reference for the stabilisation of the laser. The aim of this project, the so-called frequency reference cavity, is to reach a level of laser frequency fluctuations of better than 10^{-5} Hz/sqrt(Hz) in the detection band, centered around 200 Hz. Therefore we need to reduce the frequency noise by a factor of 10^7. The main goal is to make a sufficiently stabilised laser beam available for the AEI 10 m Prototype Interferometer, with a duty cycle that is not limiting the operation of the core instrument by any means. In my presentation I will show the motivation for a frequency stabilisation and present the layout and the current status of the reference cavity.

Q 15.74 Mon 17:00 C/Foyer

The AEI 10m-Prototype Suspension Platform Interferometer — •Sina Köhlenbeck for the AEI 10m-Prototype Team — Albert-Einstein-Institut Hannover, Max-Planck-Institut für Gravitationspyhsik und Institut für Gravitationsphysik der Universität Hannover

The AEI 10m-Prototype facility is an environment for interferometry at the Standard Quantum Limit and a place to test new techniques for the next generation of gravitational wave detectors. Such experiments require extreme isolation from external vibrations. Three optical benches are pre-isolated by a passive isolation system, which attenuates ground motion down to 0.1 Hz. Below this frequency active feedback is required to stabilise the optical benches relative to each other. Therefore the Suspension Platform Interferometer (SPI) measures the longitudinal degrees of freedom using heterodyne Mach-Zehnder interferometry and the rotational degrees of freedom using optical levers. The optical set-up and initial results are presented.

Q 15.75 Mon 17:00 C/Foyer

The AEI-SAS: Seismic isolation for the 10 m Prototype Interferometer — •Gerald Bergmann and the AEI 10m Prototype Team — Albert Einstein Institut Hannover

A 10 m arm length prototype interferometer is currently being set up at the AEI in Hanover, Germany. This facility will not only be used for developing novel techniques for future gravitational wave detectors, but furthermore it will provide a platform for high precision experiments such as measuring the standard quantum limit (SQL) of interferometry. To achieve the high requirements on displacement noise for these experiments very good isolation from seismic motion is required.

The first stage of seismic isolation for the 10 m prototype interferometer is a set of passively isolated optical tables. Geometric anti-spring filters provide vertical attenuation, and the tables are mounted on inverted pendulum legs which provide isolation in horizontal direction. Purely mechanically passive attenuation of more than 60 dB below 10 Hz was shown in first experiments. The table motion agrees very well with the predicted performance up to the lowest internal resonances above 25 Hz. Improvements of the AEI-SAS's performance at those resonances are currently tested. Several sensors and a Suspension Platform Interferometer measure the residual table motion. These signals are used for actively controlling the tables. This can even provide isolation around the isolation system's fundamental resonances.

Q 15.76 Mon 17:00 C/Foyer

Models of coherent averaging for quantum enhanced measurements — •Julien Fraisse[1,2] and Daniel Braun[1,2] — [1]Laboratoire de physique théorique, Université Paul Sabatier, 118 route de Narbonne Toulouse, France — [2]Institut für Theoretische Physik, Eberhard-Karls-Universität Tübingen, Auf der Morgenstelle 14 Tübingen, Germany

We are interested in the "coherent averaging' method' which comprises coupling N quantum resources (probes) to a $(N+1)$ system, called quantum bus and reading out the latest. It was already shown that this method allows one to reach the Heisenberg scaling (standard deviation of the estimation that scales as $1/N$ with the number of quantum resources N) in estimating a parameter linked to the interaction.

We expand this result to the estimation of a parameter linked to the free Hamiltonian of the probes, adding some constraints on the Hamiltonian, and we discuss the range of validity of our result. We study both analytically and numerically a qubit model (probes and bus are qubits) of coherent averaging. QFI calculations have been performed for this model and used to verify the general theory. We use the numerical calculation to check if the Heisenberg scaling still exists when the analytical result is not valid anymore.

Q 15.77 Mon 17:00 C/Foyer

gravitational and special-relativistic actions on x-ray superradiance — •wen-te liao[1,2,3] and sven ahrens[1,4] — [1]Max Planck Institute for Nuclear Physics, 69117 Heidelberg, Germany — [2]Max Planck Institute for the Physics of Complex Systems, 01187 Dresden, Germany — [3]Center for Free Electron Laser Science, 22607 Hamburg, Germany — [4]Beijing Computational Science Research Center, 100084 Beijing, China

Einstein's theories of relativity can be verified also in quantum systems, for example by using atomic clocks at high speeds. Such experiments offer a deeper understanding of the underlying physical phenomena. However, many challenges still remain on finding novel methods for detecting effects of gravity and of special relativity and their roles in light-matter interaction. Here we introduce a scheme of x-ray quantum optics that allows for a millimeter-scale investigation of the relativistic redshift by means of nuclei embedded in a crystal matrix. The nuclear crystal can be probed by x-rays while being held fixed in Earth's gravitational field. Alternatively, a compact rotating nuclear crystal can be used to force the interacting x-rays to experience inhomogeneous clock tick rates throughout the sample. We find that an association of gravitational or special-relativistic time dilation with quantum interference will manifest via measurable deflections of x-ray photons [1]. Our protocol suggests a new and feasible tabletop solution for probing effects of gravity and special relativity in the quantum world.

[1] W.-T. Liao and S.Ahrens, arXiv:1411.7634 (2014).

Q 15.78 Mon 17:00 C/Foyer

Electronics for Quantum Optics on a Sounding Rocket — •Thijs Wendrich, Hossein Abedi, Wolfgang Bartosch, Manuel Popp, and Ernst Maria Rasel for the QUANTUS-Collaboration — Leibniz Universität Hannover, Institut für Quantenoptik

Microgravity experiments with ultra cold degenerate quantum gases offer possibilities to test fundamental laws of physics to unprecedented precision. However, the apparatuses to make these measurements must be very compact and robust to operate in microgravity. Especially the operation of such an experiment on a sounding rocket to obtain several minutes of microgravity poses stringent requirements on the mass, volume and especially the reliability of the experiment. Due to these requirements, almost everything had to be designed ourselves for the MAIUS rocket missions.

In this poster we present the electronic systems of the MAIUS matter-wave microgravity experiments and some of its subcomponents like laser current drivers, BEC-chip current drivers and FPGA-based laser frequency controllers with automatic spectroscopy locking developed for these and other microgravity projects.

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Q 15.79 Mon 17:00 C/Foyer

Nuclear spin mediated quantum error correction in diamond — •Florian Frank and Thomas unden — Institut für Quantenoptik, Uni Ulm

Nuclear spin mediated quantum error correction in diamond

Q 15.80 Mon 17:00 C/Foyer

Elementary analysis of frequency-difference resonances and possible realizations — •Enno Giese[1], William B. Case[1,2], Karl Vogel[1], Wolfgang P. Schleich[1,4], Manfred Kleber[3], Marlan O. Scully[4], and Roy J. Glauber[5,4] — [1]Institut für Quantenphysik and Center for Integrated Quantum Science and Technology, U Ulm — [2]Department of Physics, Grinell College, Grinell, USA — [3]Physik Department T30, TU München — [4]Institute for Quantum Science and Engerneering, Texas A&M Univ., College Station, USA — [5]Lyman Laboratory, Harvard Univ., Cambridge, USA

It is well known from nonlinear optics that a strong drive field may create two fields whose frequencies add up to the drive frequency. We refer to this phenomenon as as frequency-*sum* resonance. It can be understood in terms of intuitive energy conservation.

On the other hand, a frequency-*difference* resonance where the drive frequency is the difference of two the frequencies of the generated fields is much more counterintuitive. A physical realization of such a resonance could open a field to novel light sources. In our work we present a simple analytic model in which frequency-difference resonances occur. It is a conventional oscillator coupled to an oscillator with inverted energy spectrum, that is, with negative kinetic and negative potential energy. In this case, we find exponential gain for both oscillators if the resonance condition is fulfilled, i. e. the amplitudes of both oscillators increase simultaneously. Moreover, we discuss examples of physical systems where one of the oscillators can be interpreted as an inverted one, although only in a limited range of validity.

Q 15.81 Mon 17:00 C/Foyer

Improved generation of squeezed states of light at 532 nm by frequency up-conversion from 1550 nm — •Jan Gniesmer[1,2], Christoph Baune[1], Axel Schönbeck[1], Jaromír Fiurášek[3], and Roman Schnabel[1,4] — [1]Institut für Gravitationsphysik, Leibniz Universität Hannover and Max-Planck-Institut für Gravitationsphysik (Albert-Einstein-Institut), Callinstrasse 38, 30167 Hannover, Germany — [2]Institut für Festkörperphysik, Leibniz Universität Hannover, Appelstraße 2, 30167 Hannover, Germany — [3]Department of Optics, Palacký University, 17. listupadu 12, 77146 Olomouc, Czech Republic — [4]Institut für Laserphysik und Zentrum für Optische Quantentechnologien, Universität Hamburg, Luruper Chaussee 149, 22761 Hamburg, Germany

Frequency up-conversion of non-classical states of light provides access to so-far inaccessible wavelengths. Vollmer et al. demonstrated squeezed vacuum states at 532 nm with a noise suppression of 1.5 dB [1]. These were generated by up-conversion of squeezed states at the telecom wavelength 1550 nm. We report on improvements of the same optical setup to achieve stronger squeezing. In particular this involves characterization of the initial squeezing at 1550 nm, better upconversion efficiency and an advanced homodyne detection setup at 532 nm. The latter has a detection efficiency of 90%. These squeezed states can be used in downstream experiments, for example to improve the sensitivity of an interferometer.

[1] C. E. Vollmer et al., *Phys. Rev. Lett.* **112**, 073602 (2014)

Q 15.82 Mon 17:00 C/Foyer

Programming quantum interference in scattering materials — •Tom A.W. Wolterink, Georgios Ctistis, Simon R. Huisman, Thomas J. Huisman, Allard P. Mosk, and Pepijn W.H. Pinkse — MESA+ Institute for Nanotechnology, University of Twente, Enschede, The Netherlands

Wavefront shaping allows for ultimate control of light propagation in multiple-scattering media by adaptive manipulation of incident waves. We have demonstrated a method to program general multiport linear optical circuits in multiple-scattering materials by phase modulation of incident wavefronts. Applying this method to quantum light makes it possible to use these optical circuits for adaptive quantum optical experiments, with high flexibility in the control of quantum interference between multiple optical modes.

To this end we have constructed a bright single-photon source, producing heralded single-photon states with a measured production rate of $> 10^6$ s^{-1}. We have demonstrated that we are able to control the propagation of these single-photon states in random-scattering media, and we are currently investigating Hong-Ou-Mandel interference in these circuits.

Q 15.83 Mon 17:00 C/Foyer

Towards active optical standard based on a bad-cavity superradiant laser: challenges and approaches — •Georgy Kazakov and Thorsten Schumm — Institute of Atomic and Subatomic Physics, Vienna University of Technology, Stadionallee 2, 1020 Vienna, Austria

An active optical frequency standard, where the atomic ensemble itself produces a highly stable and accurate frequency signal, is a promising source of ultranarrow coherent laser radiation. The short-time frequency stability of such standards may overcome the stability of lasers stabilized to macroscopic cavities which are used as local oscillators in the modern optical frequency standard systems. The main idea is to create a "superradiant" laser operating deep in the bad cavity regime, where the decay rate of the cavity field significantly exceeds the decoherence rate of the lasing transition. This idea is actively studied in several groups, although the metrology relevant level of short-time frequency stability is still not achieved. We consider different approaches towards the realization of an active optical frequency standard, and discuss the required parameters of atomic ensembles. Also we consider different theoretical methods of describing of such standards.

Q 15.84 Mon 17:00 C/Foyer

Coupled polymer waveguide arrays by direct laser writing — •Christina Joerg[1], Michael Renner[1], and Georg von Freymann[1,2] — [1]Department of Physics and State Research Center OPTIMAS, University of Kaiserslautern, Erwin-Schroedinger-Str. 56, 67663, Kaiserslautern, Germany — [2]Fraunhofer-Institute for Physical Measurement Techniques IPM, Erwin-Schroedinger-Str. 56, 67663, Kaiserslautern, Germany

Our goal is to build a compact photonic quantum simulator for the electronic properties of, e.g., graphen. As the propagation distance z in the paraxial Helmholtz equation corresponds to time in the Schrödinger equation one can simulate quantum-optical effects by looking at the propagation of light in coupled waveguides.

To do so we fabricate single-mode waveguide arrays on a micrometer scale via direct laser writing (two photon absorption) in negative photoresist. After writing the inverse of the waveguide arrays the sample is developed and then infiltrated. By choosing appropriate infiltration materials the coupling constant between waveguides can be tuned. For a start we use soft-baked SU8, corresponding to a contrast in the refraction index of 0.03 and coupling lengths of about 50um.

Writing samples of different height we can observe the light pattern evolution at the output facet when focusing a laser beam onto the input facet of the waveguide sample.

First experimental results and numerical calculations are presented.

Q 15.85 Mon 17:00 C/Foyer

Propagation of nanofiber-guided light through an array of atoms — •Fam Le Kien[1,2] and Arno Rauschenbeutel[2] — [1]Wolfgang Pauli Institute, Oskar Morgensternplatz 1, 1090 Vienna, Austria — [2]VCQ, TU Wien, Atominstitut, Stadionallee 2, 1020 Vienna, Austria

We study the propagation of nanofiber-guided light through an array of atomic cesium, taking into account the transitions between the hyperfine levels $6S_{1/2}F = 4$ and $6P_{3/2}F' = 5$ of the D_2 line. We derive the coupled-mode propagation equation, the input-output equation, the scattering matrix, the transfer matrix, and the reflection and transmission coefficients for the guided field in the linear, quasistationary, weak-excitation regime. We show that, when the initial distribution of populations of atomic ground-state sublevels is independent of the magnetic quantum number, the quasilinear polarizations along the principal axes x and y, which are parallel and perpendicular, respectively, to the radial direction of the atomic position, are not coupled to each other in the linear coherent scattering process. When the guided probe field is quasilinearly polarized along the major principal axis x, forward and backward scattering have different characteristics. When the array period is far from the Bragg resonance, the backward scattering is weak. Under the Bragg resonance, most of the guided probe light can be reflected back in a broad region of field detunings even though there is an irreversible decay channel into radiation modes. When the atom number is large enough, two different band gaps may be formed, whose properties depend on the polarization of the guided probe field.

Q 15.86 Mon 17:00 C/Foyer

Towards nonlinear optics with cold Rydberg atoms inside a hollow-core fiber — •Maria Langbecker, Mohammad Noaman, and Patrick Windpassinger — Universität Mainz, QUANTUM, Institut für Physik, Staudingerweg 7, 55128 Mainz, Germany

Cold atoms inside hollow-core fibers present a promising system to study strongly nonlinear light-matter interaction. Combined with the long range Rydberg interaction and the possibility to tune the interaction strength through an EIT process, a corresponding experimental setup should allow for the generation of a strong and tunable effective photon-photon interaction [1]. As a consequence, novel states light can be generated and studied.

We present an experimental setup where laser cooled Rubidium atoms are transported into a hollow-core Kagomé fiber. The fiber properties allow for simultaneous atom trapping and Rydberg-EIT excitation and we discuss the progress towards this first step for nonlinear Rydberg physics in a quasi-one-dimensional geometry.

[1] Otterbach et al., PRL 111, 113001 (2013)

Q 15.87 Mon 17:00 C/Foyer

Highly Efficient Free-Space Atom-Light Interface — •Lucas Alber[1,2], Marianne Bader[1,2], Martin Fischer[1,2], Simon Heugel[1,2], Markus Sondermann[1,2], and Gerd Leuchs[1,2,3] — [1]Max-Planck-Institute for the Science of Light, Erlangen, Germany — [2]Friedrich-Alexander University Erlangen-Nürnberg (FAU), Department of Physics, Erlangen, Germany — [3]Department of Physics, University of Ottawa, Canada

We present an optical setup capable of transforming a paraxial Gaussian-beam into a spherical linear dipole wave. This is accomplished by focusing a radially polarized beam with a parabolic mirror covering 94% of the solid angle relevant for a linear dipole. The mode is interfaced to an ion at the focus of the parabolic mirror, providing an ideal probe for the created mode. By reducing our focusing geometry to half solid-angle we are able to monitor the upper-level population of the driven transition, measuring the light scattered by the ion into the complementary solid angle part. Varying the incident power we determine the coupling efficiency to the linear dipole to be 27%. Our setup demonstrates the highest efficiency for coupling between light and a single emitter in free space reported so far.

Q 15.88 Mon 17:00 C/Foyer

Frequency stabilization of a triply resonant whispering-gallery mode resonator — •Navid soltani, Joanna Janas, Gerhard Schunk, Ulrich Vogl, Michael Förtsch, Dmitry Strekalov, Florian Sedlmeir, Harald Schwefel, Gerd Leuchs, and Christoph Marquardt — Max Planck Institute for Science of Light

We present a compact source of photon-pairs and squeezed light based on efficient parametric down conversion in a triply resonant whispering-gallery resonator (WGR) made out of lithium niobate. To achieve stable frequency emission it is important to control the temperature of the system. We present various approaches to improve the temperature stability of the system. This allows for experiments involving coupling the emitted light or the evanescent field to narrow-band systems such as atomic transitions or optomechanical resonators.

Q 15.89 Mon 17:00 C/Foyer

Tailoring single photons via heralding — •Valentin Averchenko, Michael Förtsch, Christoph Marquardt, Markus Sondermann, Andrea Aiello, and Gerd Leuchs — Max-Planck-Institut fur die Physik des Lichts, Gunther-Scharowsky-Str. 1 Bau 24, 91058 Erlangen, Germany

In this work we develop a shaping method that uses intrinsic temporal/spectral quantum correlations (entanglement) of photon pairs produced in the parametric down-conversion process. Then, in contrast to the direct photon filtering, shaped photon is generated in a heralded way, been conditioned on the detection of its twin. We build corresponding theory and make parameter estimations. The work brings together two state-of the art experiments currently running in MPL: light-atom coupling in a free space and the single-photon generation in a whispering gallery mode resonator.

Q 15.90 Mon 17:00 C/Foyer

Optical trapping of nano-crystals with a deep parabolic mirror — •Vsevolod Salakhutdinov[1,2], Mathieu Manceau[3], Alberto Bramati[3], Elisabeth Giacobino[3], Markus Sondermann[1,2], and Leuchs Leuchs[1,2] — [1]Max Planck Institute for the Science of Light, Erlangen, Germany — [2]Institute of Optics, Information and Photonics, University Erlangen-Nuremberg, Erlangen, Germany — [3]Laboratoire Kastler Brossel, Université Pierre et Marie Curie, Ecole Normale Supérieure, Paris , France

Many experiments involving nanoscopic single photon emitters such as quantum dots, NV centres or organic molecules would benefit from high photon-collection efficiency. Here, we aim at demonstrating high collection efficiency for photons emitted by colloidal nano-crystals. The central element of our setup is a deep parabolic mirror (PM) covering 94% of the solid angle relevant for a linear-dipole emitter [1]. This mirror serves two purposes: ensuring high collection efficiency and trapping the nano-crystals at the mirror's focus via an optical tweezers. The trapped nano-crystals are colloidal CdSe/CdS dot-in-rod (DR) particles with a radiation pattern close to the one of a linear dipole [2]. These DRs have been shown to be promising single-photon sources at room temperature [2]. The optical trap potential is provided by focusing a radially polarized, near infra-red laser beam with the PM. We discuss the experimental set-up in detail and provide an assessment of the achieved collection efficiency.

[1] R. Maiwald et al., Phys. Rev. A 86 , 043431 (2012)
[2] F. Pisanello et al., Appl. Phys. Lett. 96, 033101 (2010)

Q 15.91 Mon 17:00 C/Foyer

Rayleigh Scattering in Open-Access Microcavities — •Eric Bersin[1,2], Julia Benedikter[1,2], Matthias Mader[1,2], Thomas Hümmer[1,2], Theodor Hänsch[1,2], and David Hunger[1,2] — [1]Ludwig-Maximilians-Universität München — [2]Max-Planck-Institute for Quantum Optics

The small mode volumes of optical microcavities provide enhanced light-matter coupling, allowing application in experiments ranging from optomechanics (1) to quantum emitters (2). Recently, interest has developed in fibre-based Fabry-Perot microcavities (3). These cavities have high finesse, sub-cubic micrometer mode volumes, and an open-access cavity volume. Unlike other optical resonators (photonic crystals, WGM resonators, etc.), these cavities have a readily tunable length, and offer unique capabilites for mode mixing by virtue of their variable effective numerical apertures. The combination of these properties gives these devices intriguing potential for application, most recently in scanning cavity microscopy (4). However, such experiments require placing objects inside the cavity mode volume, raising questions about how the presence of such scatterers might affect the cavity's performance. We report theoretical predictions and experimental results of how Rayleigh scatterers in the cavity mode volume affect fundamental properties such as finesse and mode mixing.

(1) P. Asenbaum et al, Nature Communications 4, 2743 (2013).
(2) H. Kaupp et al, Phys. Rev. A 88, 053812 (2013).
(3) D. Hunger et al, New J. Phys. 12, 065038 (2010).
(4) M. Mader et al, arXiv:1411.7180 (2014).

Q 15.92 Mon 17:00 C/Foyer

Precision polarimeter for state-dependent optical lattices — •Muhammad Sajid, Dieter Meschede, Andrea Alberti, Stefan Brakhane, and Wolfgang Alt — Institut f\"ur Angewandte Physik der Universit\"at Bonn, Wegelerstr. 8, 53115 Bonn

State-dependent optical lattices for single neutral atoms are a key component in the experimental realization of discrete-time quantum walks [1], which can be used to simulate complex physical systems [2]. A polarization based state-dependent lattice requires the dynamical synthesization of arbitrary polarization states of the laser beams forming the lattice with a very high precision.

We will report on a rotating quarter-wave-plate Stokes polarimeter that will be used as an independent measure of the lattice polarization in order to monitor the polarization synthesis. The benefit of such a dynamical polarimeter with a single photo detector consists in the absence of calibration errors between different detectors which are used in static polarimeters.

References: [1] M. Karski et al. Quantum Walk in Position Space with Single Optically Trapped Atoms, Science 325, 174 (2009). [2] M. Genske et al. Electric quantum walks with individual atoms, Phys. Rev. Lett. 110, 190601 (2013)

Q 15.93 Mon 17:00 C/Foyer

A broadband photon echo scheme for quantum storage — •Xiangjin Kong[1], Wen-Te Liao[1,2,3], Christoph H. Keitel[1], and Adriana Pálffy[1] — [1]Max Planck Institute for Nuclear Physics, Heidelberg — [2]Max Planck Institute for the Physics of Complex Systems, Dresden — [3]Center for Free Electron Laser Science, Hamburg

A broadband photon echo effect in a three level Lambda-type system interacting with two laser fields is investigated theoretically [1]. Inspired by the emerging field of nuclear quantum optics which typically deals with very narrow resonances, we consider broadband probe pulses that couple to the system in the presence of an inhomogeneous control field. We show that ideally, such a setup provides an all-electromagnetic-field solution to implement high bandwidth photon echoes, which are easy to control, store and shape on a short time scale [1]. Numerical results for realistic experimental parameters as well as an extension or our setup for chirped pulses are also presented. Our results may pave the way towards ultrafast processing and high-performance photonic devices.

[1] W.-T. Liao, C. H. Keitel and A. Pálffy, Phys. Rev. Lett. 113, 123602 (2014).