Q 57: Poster 3: Quantengase, Ultrakalte Atome, Ultrakalte Moleküle, Materiewellen Optik, Präzisionsmessungen, Metrologie

Time: Thursday 16:30–19:30 Location: P1

Q 57.1 Thu 16:30 P1

Weak Localisation with Short Loops — •Felix Eckert, Thomas Wellens, and Andreas Buchleitner — Physikalisches Institut, Albert-Ludwigs Universität, Freiburg, Germany

In multiply scattering weakly disordered media (i.e. the wavelength $\lambda \ll$ mean free path ℓ), the average wave intensity is known to obey a diffusion equation. It is also well understood that interference effects lead to reduction of the diffusion, termed "weak localisation" and expressed by a decrease of the diffusion coefficient. These interference effects can be explained in terms of pairs of counterpropagating loops interfering constructively, thus enhancing the probability of return.

In the usual approach, these loops are calculated within the diffusion approximation, thus completely neglecting short loops, i.e. loops that consist of only a few scattering events. We present a calculation of the weak localisation corrections treating the propagation inside the loops exactly thus accounting also for the short loops. We find that the leading order correction to the diffusion coefficient scales linearly in λ/ℓ as opposed to the $(\lambda/\ell)^2$ predicted by the usual approach.

Q 57.2 Thu 16:30 P1

Many boson- vs. many-fermion interference – differences and similarities — •Malte C. Tichy[1], Markus Tiersch[2], Florian Mintert[1,3], and Andreas Buchleitner[1] — [1]Physikalisches Institut - Universität Freiburg - Hermann-Herder-Str. 3 - D-79104 Freiburg — [2]Institute for Quantum Optics and Quantum Information - Austrian Academy of Sciences - Technikerstr. 21A - A-6020 Innsbruck, Austria — [3]Freiburg Institute for Advanced Studies - Universität Freiburg - Albertstr. 19 - D-79104 Freiburg

We discuss many-particle interference in the scattering of an arbitrary number of non-interacting bosons, fermions, or distinguishable particles within general scenarios. For the case of Fourier multiport beam splitters, a suppression law is derived [1] for both bosons and fermions, providing a generalization of the two-photon Hong-Ou-Mandel effect. In general, the intuitive dichotomy of bosons and fermions, known from the two-particle case, does, surprisingly, not prevail for more than two particles. The statistical behavior of identical particles – bunching for bosons and the Pauli principle for fermions – and many-particle interference that governs the particles' behavior in any scattering scenario need to be considered as two largely independent effects.

[1] M.C. Tichy et al., Phys. Rev. Lett. 104, 220405 (2010)

Q 57.3 Thu 16:30 P1

Nonlinear BEC Dynamics Induced by Harmonic Modulation of Atomic s-wave Scattering Length — •Ivana Vidanović[1], Antun Balaž[1], Hamed Al-Jibbouri[2], and Axel Pelster[3] — [1]Scientific Computing Laboratory, Institute of Physics Belgrade, University of Belgrade, Pregrevica 118, 11080 Belgrade, Serbia — [2]Institut für Theoretische Physik, Freie Universität Berlin, Arnimallee 14, 14195 Berlin, Germany — [3]Fachbereich Physik, Universität Duisburg-Essen, Lotharstrasse 1, 47048 Duisburg, Germany

In the recent experiment [1], a Bose-Einstein condensate of ^{7}Li has been excited by a harmonic modulation of the atomic s-wave scattering length via Feshbach resonance. Combining an analytical perturbative approach with numerical simulations we analyze the resulting nonlinear dynamics of the system on the mean-field Gross-Pitaevskii level. Our detailed results show the presence of higher harmonics and mode coupling. Most importantly, we also find significant shifts of the collective modes frequencies in the resonance region which are due to the nonlinearity of the system dynamics. Finally, we indicate how these frequency shifts could be measured in a future experiment.

[1] S. E. Pollack et. al., PRA **81**, 053627 (2010).

Q 57.4 Thu 16:30 P1

Exact Lieb-Liniger Dynamics — •Jan Zill[1,2], Matthias Kronenwett[1,2], and Thomas Gasenzer[1,2] — [1]Institut für Theoretische Physik, Ruprecht-Karls-Universität Heidelberg, Philosophenweg 16, 69120 Heidelberg — [2]ExtreMe Matter Institute EMMI, GSI Helmholtzzentrum für Schwerionenforschung GmbH, Planckstr. 1, 64291 Darmstadt

A one-dimensional gas of Bosons with repulsive delta-function interactions is studied. The ground state and the (low lying) excitation spectrum for fixed particle numbers and different interaction strengths are computed numerically via the Bethe-Ansatz and an extended Fermi-Bose mapping. We aim to compute the time evolution of the momentum distribution for weak and strong interaction strength, as well as of other correlation functions. Since the Schrödinger equation is solved exactly, the results can be used as a benchmark for approximative analytical and numerical methods in quantum field theory.

Q 57.5 Thu 16:30 P1

Back reaction from Bogoliubov modes onto grey solitons — •Philip Walczak and James Anglin — TU Kaiserslautern, Erwin-Schrödinger-Str. 46, 67663 Kaiserslautern

In quasi-one-dimensional Bose-condensed gases one can observe the formation of so-called grey solitons in the semi-classical limit. These are large phase and amplitude slips occurring on healing length scales. The dynamics of grey solitons is described by the non-linear Gross-Pitaevskii equation. We have found the exact solutions of the linearized problem of small excitations around a general grey soliton background. These excitations can be viewed as traveling waves in a perfectly non-reflecting potential provided by the soliton. It can be seen that asymptotically the effect of the soliton on these modes is a wave number dependent phase shift. From momentum and energy conservation one can conclude that in turn the passage of the excitations must induce a finite spatial translation the soliton. We derive an analytical expression for this classical back reaction 'dragging' effect in the case of an initial Gaussian wave packet, which is in good agreement with numerical propagation under the full non-linear equation. We discuss differences between quantum and classical back reaction.

Q 57.6 Thu 16:30 P1

Towards the realization of an erbium atomic quantum gas — •Henning Brammer, Jens Ulitzsch, Riad Bourouis, and Martin Weitz — Institut für Angewandte Physik, Universität Bonn

The erbium atom has a $4f^{12}6s^2\ ^3H_6$ electronic ground state with a large angular momentum of $L = 5$. So far realized atomic quantum gases all have been realized with a spericall symmetric ($L = 0$) s-ground state configuration, for which in far detuned laser fields with detuning above the upper state fine structure splitting the trapping potential is determined by the scalar electronic polarizability. In contrast, for an erbium quantum gas with its $L > 0$ ground state, the trapping potential also for far detuned dissipation-less trapping laser fields becomes dependent on the internal atomic state (i.e. spin).

We have reported on progress in an ongoing experiment directed at the generation of an atomic erbium Bose-Einstein condensate by evaporative cooling in a far detuned optical dipole trap. In the present stage of the experiment, a magneto optical trap (MOT) for this rare earth metal atom has been realized, loaded from an effusive cell and decelerated by a Zeeman slower. The experiment uses a single laser frequency tuned to the red of the $400,91nm$ cooling transition. No repumping radiation is required for the MOT operation, despite the complex energy level structure of erbium and therefore the presence of several leak channels. This is attributed to the high magnetic moment of the erbium atom ($7\mu_B$), which allows a magnetic trapping of erbium atoms left in metastable energy levels in the MOT gradient magnetic field. Experimental data of the erbium MOT will be shown.

Q 57.7 Thu 16:30 P1

Dipole potentials for guided atom-optics — •Thomas Lauber, Johannes Küber, Martin Hasch, Oliver Wille, and Gerhard Birkl — Institut für Angewandte Physik, Technische Universität Darmstadt, Schlossgartenstraße 7, 64289 Darmstadt

We present our approach towards integrated atom-optics, which is based on the implementation of micro-fabricated optical elements for the shaping of dipole potentials. These elements are available in various designs like cylindrical lens arrays or a ring lens. They provide the advantage that the resulting light fields can be easily combined to create complex structures, like beam splitters or Mach-Zehnder like interferometers. The ring lens, which offers a toroidal trapping potential, is currently investigated. We present first experiments with a Bose-Einstein condensate loaded to and accelerated in linear wave guides and the ring shaped dipole potential.

For these experiments we use a BEC which is prepared all-optically in a crossed dipole trap generated by a 1070nm fibre laser. For coherent splitting and acceleration of the atoms we use a one-dimensional optical lattice. With this setup we are able to perform interferometric experiments for characterisation of the coherence properties in a wave guide.

We further show a possible scheme for an atom matter wave resonator with tunable mirror transmittance, which reveals long lifetimes and specific revival dynamics.

Q 57.8 Thu 16:30 P1

Scaling laws of turbulent ultracold bosons — •Boris Nowak[1,2], Maximilian Schmidt[1,2], Jan Schole[1,2], Denes Sexty[1,2], and Thomas Gasenzer[1,2] — [1]Institut für Theoretische Physik, Ruprecht-Karls-Universität Heidelberg, Philosophenweg 16, 69120 Heidelberg — [2]ExtreMe Matter Institute EMMI, GSI Helmholtzzentrum für Schwerionenforschung GmbH, Planckstraße 1, 64291 Darmstadt, Germany

Turbulent dynamics in an ultracold Bose gas, in two and three spatial dimensions, is studied analytically and numerically. A special focus is set on the infrared regime of large-scale excitations following universal power-law distributions distinctly different from those of commonly known weak wave-turbulence phenomena. The infrared power laws which have been predicted within an analytic field-theoretic approach based on the 2PI effective action, are discussed in comparison to the well-known Kolmogorov scaling of vortical motion. These phenomena of strong turbulence should in principle be observable with ultracold atomic gases.

Q 57.9 Thu 16:30 P1

Critical dynamics of ultracold bosons in one dimension — •Maximilian Schmidt[1,2], Jan Schole[1,2], Boris Nowak[1,2], Denes Sexty[1,2], and Thomas Gasenzer[1,2] — [1]Institut für Theoretische Physik, Ruprecht-Karls-Universität Heidelberg, Philosophenweg 16, 69120 Heidelberg — [2]ExtreMe Matter Institute EMMI, GSI Helmholtzzentrum für Schwerionenforschung GmbH, Planckstraße 1, 64291 Darmstadt, Germany

Critical dynamics in an ultracold Bose gas, in one spatial dimension, is analysed with respect to topological excitations and compared to quantum turbulence in two and three dimensions. A special focus is set on the time-evolution of characteristic quantities such as the energy and velocity distributions, soliton and vortex densities and the spectral function. The results give insight into the structure of stationary states of an ultracold Bose gas away from equilibrium.

Q 57.10 Thu 16:30 P1

Bose-Einstein condensation of a two-dimensional photon gas and prospects on its realization in solid-state materials — •Julian Schmitt, Jan Klaers, Frank Vewinger, and Martin Weitz — Institut für Angewandte Physik (IAP), Universität Bonn

Bose-Einstein condensation has been experimentally demonstrated in several physical systems, including cold atomic gases and solid-state quasiparticles. Owing to its vanishing chemical potential blackbody radiation does not collectively occupy the lowest energy mode when the temperature is lowered - but instead the photons disappear in the cavity walls. We describe a thermalized two-dimensional photon gas with a freely adjustable chemical potential based on a dye-filled microresonator. Thermalization to the temperature of the resonator is achieved by photon scattering off the dye molecules, and the cavity mirrors provide both an effective photon mass and a confining harmonic potential. This allows for Bose-Einstein condensation of photons, which is experimentally observed at sufficiently high photon densities. In more recent experiments, we have realized a thermalized photon gas in a solid state system. Dye molecules embedded in polymeric host matrices allow for multiple emission and reabsorption processes of the photons driving the system to thermal equilibrium, with the occupation of transversal modes being Boltzmann-like. In correspondence to our experiments carried out on the liquid dye solution, a spatial concentration effect of the light to the centre of the confining potential is observed. However, the experiment reveals a sensitive dependence of the spatial redistribution extent on the fluorescence quantum yield of the dye molecules.

Q 57.11 Thu 16:30 P1

Quantum - classical correspondence and break-down of second Josephson oscillations — •Martin P. Strzys and James R. Anglin — Technische Universität Kaiserslautern, FB Physik, 67663 Kaiserslautern, Germany

A simple four-mode Bose-Hubbard model with intrinsic time-scale separation can can be considered as a paradigm for mesoscopic quantum systems in thermal contact. Bogoliubov excitations of the two-mode subsystems thereby behave similarly to second sound phenomenons in liquid Helium II and perform second Josephson oscillations. We will illuminate the quantum classical correspondence and the range of validity of this theory.

Q 57.12 Thu 16:30 P1

Investigation of light-assisted collisions of ^{40}Ca — •Oliver Appel, Max Kahmann, Stephan Schulz, Sebastian Kraft, Fritz Riehle, and Uwe Sterr — Physikalisch-Technische Bundesanstalt (PTB), Bundesallee 100, 38116 Braunschweig

Quantum degenerate Calcium is an interesting candidate for atom interferometry and optical Feshbach resonances. Therefore it is necessary to investigate collisions involving at least one excited atom. We use photoassociation spectroscopy to search for bound molecular states near the $^1S_0$-$^3P_1$ asymptote. By optically coupling these bound states to the ground state we will be able to generate an optical Feshbach resonance. In contrast to magnetic Feshbach resonances these can be used to modify the scattering length on very small length scales.

To further understand collisions of unbound ^3P atoms we excite into the $^3P_1$ and $^3P_0$ states and study the coherence loss. The excitation to the long-lived $^3P_0$ state demands for an ultranarrow laser, which is being set up.

In this poster we will report on the current status of the experiment. Our work is supported by the excellence cluster QUEST.

Q 57.13 Thu 16:30 P1

Low-dimensional physics on atom chips — •Anton Piccardo-Selg, Gal Aviv, Simon Goodall, Lucia Hackermüller, Thomas Fernholz, and Peter Krüger — School of Physics and Astronomy, University of Nottingham, NG7 2RD, United Kingdom

Atom chips allow for almost arbitrary trapping geometries for atomic ensembles by means of magnetic, electric, optical, microwave and radio-frequency potentials. Our research aims at the creation of multiply connected topologies, like rings, tori, and cylinders. These traps are used to investigate the low temperature behaviour of ultracold quantum gases when the dimensionality of the trapping geometry changes.

Our current atom chip generation will produce cylinder-symmetric traps by using a combination of dc and radio-frequency fields. Further to the investigation of low-dimensional systems the chip can be used to dynamically split an elongated cloud of ultracold atoms. This “unzipping” of the cloud is intended to be used as a quantum simulator for the dynamical Casimir effect. The current progress of the experimental setup will be presented.

Q 57.14 Thu 16:30 P1

Cold Heat - The Quantum Kinetic Theory of Collisionless Superfluid Internal Convection — •Lukas Gilz and James Anglin — TU Kaiserslautern, Kaiserslautern, Germany

When a superfluid is heated locally, condensate and non-condensate fractions flow in opposite directions. As if to rebut the 19th century conclusion that cold is merely absence of heat, condensate flows like a flux of cold, from cooler regions to hotter. Wereas this phenomenon of ”superfluid internal convection” is usually described within Landau’s phenomenological two fluid model, we obtain a more fundamental picture of internal convection by extending a standard master equation formulation of quantum kinetic theory to include two reservoirs of different temperatures. We find that internal convection occurs even in collisionless regimes and that coherent scattering is essential to the observation of a condensate flow. Besides computing estimates of particle-, energy- and entropy flow, we propose an experimental approach by which this behavior can be observed in trapped ultracold Bose gases.

Q 57.15 Thu 16:30 P1

Scattering Ultracold Atoms on Carbon Nanotubes — •Peter Federsel[1], Michael Gierling[1], Philip Schneeweiss[1], Gabriela Visanescu[1], Dieter Kern[2], Andreas Günther[1], and József Fortágh[1] — [1]Physikalisches Institut der Universität Tübingen Auf der Morgenstelle 14 D-72076 Tübingen — [2]Institut für Angewandte Physik Universität Tübingen Auf der Morgenstelle 10 D-72076 Tübingen

We measure the inelastic scattering cross section between ultracold rubidium atoms and carbon nanotubes. The measurement is done by spatially overlapping ultracold thermal clouds and Bose-Einstein condensates with a single carbon nanotube and recording the atom loss. From the data we derive the velocity dependent scattering radius of the nanotube.

Q 57.16 Thu 16:30 P1

Interactions and crossovers between insulating phases of fermionic gases in optical lattices — •Victor Hugo Ferreira Bezerra[1], Flavio de Souza Nogueira[1], and Axel Pelster[2] — [1]Institut für Theoretische Physik, Freie Universität Berlin, Arnimallee 14, 14195 Berlin, Germany — [2]Fachbereich Physik, Universität Duisburg-Essen, Lotharstrasse 1, 47048 Duisburg, Germany

Recent experimental progress in the field of cold atoms has boosted a world-wide quest to simulate condensed matter problems within the realm of ultracold quantum gases in optical lattices. A considerable progress was achieved last years with the realization of a fermionic Mott insulator in an optical lattice. Several groups are now focusing experimental and theoretical efforts to realize the BEC-BCS crossover and different magnetic phases in optical lattices. In this work we investigate the phase structure for interacting fermions near a Feshbach resonance in two- and three-dimensional cubic lattices. To this end we have analyzed the underlying Hubbard-like model with a recently developed field-theoretic many-body technique to describe crossovers and transitions between the diferent phases related to superconducting and antiferromagnetic instabilities. In particular, we have calculated the quantum effective action and obtained in the strongly correlated regime a crossover between magnetic and charge ordered insulators. This crossover corresponds to the strongly correlated counterpart of the BCS-BEC crossover, which for our lattice model occurs in the weakly coupled regime.

Q 57.17 Thu 16:30 P1

A new setup for the study of strongly correlated low-dimensional systems — •Florian Wittkötter, Wolf Weimer, Kai Morgener, Niels Strohmaier, and Henning Moritz — Institut für Laser-Physik, Universität Hamburg, Luruper Chaussee 149, 22761 Hamburg

We present our new experimental setup for the study of low-dimensional Fermi gases with local control and readout. A gas of fermionic Lithium is cooled to quantum degeneracy and prepared between two microscope objectives. A novel ring resonator concept will be used for creating one-dimensional systems and the Fermi-Hubbard model. In combination with the excellent optical access this allows us to address non-equilibrium phenomena in strongly correlated systems.

Q 57.18 Thu 16:30 P1

Approaching a three-component Fermi gas in an optical lattice — •Martin Ries[1,2], Andre Wenz[1,2], Philipp Simon[1,2], Thomas Lompe[1,2], Friedhelm Serwane[1,2], Gerhard Zürn[1,2], and Selim Jochim[1,2] — [1]Physikalisches Institut, Universität Heidelberg — [2]Max-Planck-Institut für Kernphysik

We report on our progress towards the realization of a three-component Fermi gas of ^{6}Li atoms in a two-dimensional optical lattice. A three-component Fermi gas with its approximate SU(3) symmetry can serve as a simplified model system for QCD problems. In free space, however, the gas is not stable due to a large three-body loss rate. This issue can be overcome with the help of a lattice potential, which is predicted to block three-body losses and thus to stabilize the system.

We have set up a magneto-optical trap, from which precooled atoms will be transferred to an optical dipole trap and evaporatively be cooled to degeneracy. They will then be transferred into a two-dimensional optical lattice.

Q 57.19 Thu 16:30 P1

Bosons and fermions in three-dimensional optical lattices: Multi-band and nonlinear hopping corrections — •Alexander Mering and Michael Fleischhauer — Fachbereich Physik and research center OPTIMAS, Technische Universität Kaiserslautern

Recent experiments revealed the importance of higher-band effects for the Mott insulator – superfluid transition of ultracold bosonic atoms or mixtures of bosons and fermions in deep optical lattices [Best *et al.*, PRL **102**, 030408 (2009); Will *et al.*, Nature **465**, 197 (2010)]. In the present work, we derive an effective lowest-band Hamiltonian in 3D that generalizes the standard Bose-Fermi Hubbard model taking these effects into account within an adiabatic elimination scheme of virtual transitions to higher bands. Nonlinear corrections of the tunneling amplitudes mediated by interspecies interactions being neglected so far are shown to be of equal importance. Further more, a correct description of the lattice states in terms of the bare-lattice Wannier functions turns out to be essential in contrast to approximations such as harmonic oscillator states. Especially for repulsive interactions, our approach reveals the importance of the interplay between nonlinear and higher-band corrections for the understanding of the observed shift of the MI-SF transition.

Q 57.20 Thu 16:30 P1

Interacting instabilities in spin-orbit coupled one dimensional Spinor condensates — •Frank Zimmer, Andreas Jacob, and Rejish Nath — Max-Planck-Institut für Physik komplexer Systeme, Nöthnitzer Str. 38, 01187 Dresden

Homogeneous Bose Einstein condensates with repulsive short-range interactions are always stable against small perturbations. Once spin-orbit (SO) coupling is introduced they exhibit a finite momentum instability. Such an instability may lead to the formation of standing waves in 1D or vortex arrays in 2D, depending on the interactions in the system.

If interactions are attractive, in addition to the already existing unstable finite momentum modes, unstable low momentum phonon excitations occur. They emerge due to the SO coupling present in the system. Such a novel scenario in BECs is studied by means of Landau modulation equations. We discuss in detail the possible stable solutions associated with interacting instabilities.

Q 57.21 Thu 16:30 P1

Perspectives of Few Body Physics in an Ultracold Mixture of ^{6}Li and ^{133}Cs — •Romain Müller, Marc Repp, Rico Pires, Juris Ulmanis, Stefan Schmidt, Kristina Meyer, and Matthias Weidemüller — Physikalisches Institut, Ruprecht-Karls-Universität Heidelberg, Heidelberg, Germany

The ability to precisely control the interactions in a Bose-Fermi mixture of ^{133}Cs and ^{6}Li at phase-space densities close to quantum degeneracy results in the opportunity to study many different aspects of few- and many body physics in a system with the highest mass imbalance between alkali atoms.

To observe few body effects precise characterization and tuning of interspecies interactions via magnetic field (i.e. knowledge of *Feshbach resonances*) beetween ^{133}Cs and ^{6}Li are necessary. Additionally, the extremely large mass-difference of Li and Cs results in the smallest scaling factor of all alkali combinations for the appearance of universal Efimov states of 4.88 (in comparison to 22.7 for homo-nuclear mixtures) for $^{133}Cs_2{}^6Li$. A precise control over the scattering length enables the observation of a large series of this trimer states [1,2].

In this poster we present the structure of Feshbach resonances for a mixture of ^{133}Cs and ^{6}Li that is calculated using the Asymptotic-Bound-State model [3]. We discuss the experimental approach used to study Efimov physics and other few body effects in this mixture.

[1] E. Braaten and H.-W. Hammer, AnnPhys **322**, 120 (2007)
[2] K. Helfrich *et al.*, PRA **81**, 042715 (2010)
[3] T. G. Tiecke *et al.*, PRA **82**, 042712 (2010)

Q 57.22 Thu 16:30 P1

Non-abelian Gauge-field simulators with cold atoms — •Naceur Gaaloul[1], Torben Schulze[1], Holger Ahlers[1], Sebastian Bode[1], Felix Kösel[1], Vyacheslav Lebedev[1], Wolfgang Ertmer[1], Luis Santos[2], and Ernst Rasel[1] — [1]Institut für Quantenoptik, LU Hannover — [2]Institut für Theoretische Physik, LU Hannover

The study of strongly correlated regimes using cold-atom systems is a long-standing challenge for physicists. The charge neutrality of the atoms and the consequent absence of a Lorentz force are strong limitations to this end. The experimental realization of rotating degenerate quantum gases demonstrated the potential of atomic systems to simulate charged particles subject to a uniform magnetic field. However, due to centrifugal forces and technical issues this method turned out to be of limited use. Recently, several proposals showed that preparing coherent superpositions of Zeeman sub-states of atoms which evolve adiabatically in a laser field could drive the matter wave to acquire a Berry phase. This phase translates into a non-vanishing synthetic magnetic field which could be used to engineer a Lorentz force-like for atoms. We present a practical scheme where atomic populations of a degenerate spinor system are driven by appropriate laser arrangements leading to the appearance of gauge field structures. The use of realistic parameters and atomic spectral data make of this method a receipt to implement quantum simulators of gauge fields including the general class of non-abelian (non-commutative) gauges, so far never observed for atoms.

Q 57.23 Thu 16:30 P1

Towards Bose-Fermi mixtures in disordered optical lattices — •Mathis Baumert[1], Nadine Meyer[1,2], Michael Holynski[1], Marisa Perea Ortiz[1], Kai Bongs[1], and Jochen Kronjäger[1] — [1]University of Birmingham, School of Physics & Astronomy, Birmingham, United Kingdom — [2]Universität Hamburg, Institut für Laserphysik, Hamburg, Germany

We are presenting progress towards a new setup for a ^{87}Rb - ^{40}K quantum gas mixture experiment aiming for in situ single site resolution in order to investigate disorder effects in the phase diagram.

In this poster we present glueing techniques for glass-metal window seals. This allows the use of window ports without the use of flanges, significantly reducing the size of our vacuum chamber. This in conjunction with a newly developed ultra compact magnetic coil design allows for high magnetic fields (e.g. Feshbach resonances) being generated with comparably low power.

We also present simulations for optical lattices in 2D and possible realisations of arbitrary optical potentials via SLM techniques.

We acknowledge support by EPSRC under grants EP/E036473/1 and EP/H009914/1.

Q 57.24 Thu 16:30 P1

Spontaneous Breaking of Spatial and Spin Symmetry in Spinor Condensates — Manuel Scherer[1], Bernd Lücke[1], •Jan Peise[1], Garu Gebreyesus[2], Oliver Topic[1], Frank Deuretzbacher[2], Wolfgang Ertmer[1], Luis Santos[2], Jan Arlt[3], and Carsten Klempt[1] — [1]Institut für Quantenoptik, Leibniz Universität Hannover, 30167 Hannover, Germany — [2]Institut für Theoretische Physik, Leibniz Universität Hannover, 30167 Hannover, Germany — [3]QUANTOP, Department of Physics and Astronomy, University of Aarhus, 8000 Århus C, Denmark

Spin-changing collisions can be utilized as parametric amplification of quantum fluctuations, a fundamental mechanism for spontaneous symmetry breaking. We realize a parametric amplifier for spin modes by a spinor Bose-Einstein condensate, resulting in a twofold spontaneous breaking of spatial and spin symmetry in the amplified clouds. Our experiment provides a precise analysis of the amplification of spatial Bessel-like modes, and a detailed understanding of the twofold symmetry breaking. On magnetic resonances that create vortex-antivortex superpositions, we demonstrate that the cylindrical spatial symmetry is spontaneously broken. However, spin symmetry is preserved as a consequence of phase squeezing. If nondegenerate spin modes contribute to the amplification, quantum interferences produce spin-dependent density profiles and lead to spontaneously formed patterns in the longitudinal magnetization.

Q 57.25 Thu 16:30 P1

An atomic parametic amplifier for the production of non-classical States — Manuel Scherer[1], •Bernd Lücke[1], Jens Kruse[1], Jan Peise[1], Oliver Topic[1], Frank Deuretzbacher[2], Wolfgang Ertmer[1], Jan Arlt[3], Luis Santos[2], and Carsten Klempt[1] — [1]Institut für Quantenoptik, Leibniz Universität Hannover, — [2]Institut für Theoretische Physik, Leibniz Universität Hannover — [3]QUANTOP, Department of Physics and Astronomy, University of Aarhus

In optics, parametric amplification is one of the most important tools to prepare non-classical states and investigate phenomena like squeezing and entanglement. In our experiment, we expand this process to the field of ultra cold atoms where we observe non-classical states of matter.

We use the non-linearity of the interactions in Bose-Einstein-Condensates with a spin degree of freedom to generate two entangled ensembles of atoms in the magnetic states $m_F = \pm 1$. These ensembles are analog to the signal and idler beam of an optical parametric amplifier and thus show non-classical correlations.

One effect of these correlations is a reduced fluctuation of the population of the magnetic sub-states. We measured the corresponding variance to be well below the shot-noise limit. The measurements are consistent with the properties of a twin Fock-state with exactly the same number of atoms in both sub-states. Such twin-Fock states may be used to perform interferometric measurements at the Heisenberg-limit.

Q 57.26 Thu 16:30 P1

Quantum fluctuations in the time-dependent BCS-BEC crossover — •Bernhard M. Breid and James R. Anglin — Technische Universität Kaiserslautern, Germany

We report our theoretical results on various aspects connected with the time-dependent formation of a molecular BEC out of an atomic BCS state by a slow Feshbach sweep at zero temperature. In order to solve for the systems dynamics, we apply a path integral approach using adiabatic approximations to solve for an effective action for the molecules. We are then in a position to address questions like the non-adiabatic production of quasi-particles during the sweep and the effect of different sweep rates.

Q 57.27 Thu 16:30 P1

Quantum dynamics of few ultra-cold atoms in a periodically shaken optical superlattice — Martin Esmann, Kirsten Stiebler, Bettina Gertjerenken, Niklas Teichmann, and •Christoph Weiss — Institut für Physik, Universität Oldenburg, 26111 Oldenburg

Photon-assisted tunneling is investigated both numerically and analytically in periodically shaken superlattices. While fractional photon-assisted tunneling was previously shown to be a small effect [1-3], for few particles (cf. [4]) in each of the double wells of an optical superlattice it can actually be a leading order effect. Experimentally, this should be observable with the existing experimental setup of Ref. [4]. Two-particle Schrödinger cat-states in three-well lattices are also investigated.

[1] N. Teichmann, M. Esmann, and C. Weiss, Phys. Rev. A, 79:063620, 2009.

[2] E. Haller, R. Hart, M. J. Mark, J. G. Danzl, L. Reichsöllner, and H.-C. Nägerl, Phys. Rev. Lett., 104:200403, 2010.

[3] G. Lu, W. Hai, H. Zhong, and Q. Xie, Phys. Rev. A, 81:063423, 2010.

[4] P. Cheinet, S. Trotzky, M. Feld, U. Schnorrberger, M. Moreno-Cardoner, S. Fölling, and I. Bloch, Phys. Rev. Lett., 101:090404, 2008.

Q 57.28 Thu 16:30 P1

Quantum Phase Diagram for Bosons in Optical Lattices with On-Site Interaction Modulation — •Francisco Ednilson Alves dos Santos[1] and Axel Pelster[2] — [1]Institut für Theoretische Physik, Freie Universität Berlin, Arnimallee 14, 14195 Berlin, Germany — [2]Fachbereich Physik, Universität Duisburg-Essen, Lotharstrasse 1, 47048 Duisburg, Germany

In the seminal paper [1] Walter Kohn showed with the help of Floquet theory that periodic systems, which weakly interact with a heat bath, necessarily evolve towards an equilibrium. On this basis we generalize the Ginzburg-Landau theory for bosons in optical lattices [2,3] to a single-band Bose-Hubbard Hamiltonian where the on-site interaction is periodically modulated. This allows us to characterize the location of the quantum phase transition between the Mott insulator and the superfluid for such a periodically driven system.

[1] W. Kohn, J. Stat. Phys **103**, 417 (2001).

[2] F.E.A. dos Santos and A. Pelster, Phys. Rev. A **79**, 013614 (2009).

[3] B. Bradly, F.E.A. dos Santos and A. Pelster, Phys. Rev. A **79**, 013615 (2009).

Q 57.29 Thu 16:30 P1

Magnetic phases of spinor quantum gases in hexagonal optical lattices — •Eva-Maria Richter[1], Dirk-Sören Lühmann[2], and Daniela Pfannkuche[1] — [1]I. Institut für Theoretische Physik, Universität Hamburg, Germany — [2]Institut für Laser-Physik, Universität Hamburg, Germany

Ultracold quantum gases in optical lattices have been established as a continuously growing field of research with various applications in different areas of science. While cubic lattices are theoretically and experimentally investigated in the majority of cases so far, our focus rests on spinor bosons in hexagonal lattices. By employing a triangular optical lattice with defined polarized laser beams, a hexagonal 'magnetic' optical lattice is created. Bosonic atoms in different spin quantum states are subject to different optical potentials, which depend on their internal state. Thus, the hexagonal optical lattice consists of two sublattices A and B, induced by the polarization which is mapped to an effectiv site dependent magnetic field. This leads to a spin dependent Zeeman shift beetween the two sublattices. Starting from the Bose-Hubbard-Hamiltonian and within the framework of exact diagonalization for finite systems with periodic boundary conditions we investigate the different quantum phases depending on various lattice parameters and different particle numbers. We discriminate different phases by their corresponding pair-correlation functions. Phases with next-neighbour pairing are observed as well as antiferromagnetic ordering. We compare our numerical results with those of a meanfield approximation and with experiments.

Q 57.30 Thu 16:30 P1

Non-equilibrium dynamics in a Kondo lattice of ultracold fermionic alkaline-earth-metal atoms — •Sebastian Bock[1,2], Matthias Kronenwett[1,2], Michael Foss-Feig[3], Ana Maria Rey[3], and Thomas Gasenzer[1,2] — [1]Institut für theoretische Physik, Philosophenweg 16, 69120 Heidelberg — [2]ExtreMe Matter Institute EMMI, GSI Helmholtzzentrum für Schwerionenforschung GmbH, Planckstr. 1, 64291 Darmstadt — [3]JILA, University of Colorado, Boulder CO-80309, USA

We study the dynamics of ultracold Fermi gases far from thermal equilibrium. We employ a functional-integral approach based on the Schwinger-Keldysh closed time path integral to derive the two-particle irreducible (2PI) effective action. From this, the two-point correlation functions are determined self-consistently. The action is expanded in inverse powers of N, where N is the number of atomic hyperfine states. The dynamic equations are derived in next-to-leading order of this expansion. This approach reaches far beyond mean-field theory and includes quantum statistical aspects of equilibration dynamics. This formalism is especially suited to describe far-from-equilibrium dynamics in a Kondo lattice of ultracold fermionic alkaline-earth-metal atoms where N can be as large as 10.

Q 57.31 Thu 16:30 P1

Repulsiv gebundene Teilchenpaare aus Bosonen und Fermionen im optischen Gitter — •Eva Katharina Rafeld, Bernd Schmidt und Walter Hofstetter — Institut für Theoretische Physik, Goethe-Universität Frankfurt am Main

Wir untersuchen analytisch und numerisch das Phasendiagramm repulsiv und attraktiv gebundener Teilchenpaare in optischen Gittern, die aus verschiedenen Teilchensorten bestehen (z. B. zweikomponentige Fermionen, Boson-Fermion-Paare oder Paare aus verschiedenen Bosonen). Repulsiv gebundene Teilchenpaare, die aus gleichen Bosonen bestehen, wurden schon experimentell realisiert und auch theoretisch untersucht. Bei Teilchenpaaren, die aus verschiedenen Teilchensorten bestehen, hat man jedoch noch eine viel größere Flexibilität, die effektive Wechselwirkung zwischen den Paaren einzustellen. Wir leiten daher die effektiven Vielteilchen-Hamiltonoperatoren für die unterschiedlichen Teilchenpaare her. Da die effektiven Hamiltonoperatoren der Paare dem Spin-1/2 XXZ Modell äquivalent sind, ist es dank der Flexibilität der effektiven Wechselwirkung möglich, sämtliche Phasen, die das XXZ Model aufweist, auch bei den Teilchenpaaren zu beobachten. Im eindimensionalen Fall berechnen wir dazu Teilchenzahlverteilungen und Korrelationen der Paare im harmonischen Fallenpotential und im Kastenpotential mit Hilfe der Time Evolving Block Decimation (TEBD) Methode. Da das Phasendiagramm des Spin-1/2 XXZ Model in 1d analytisch exakt bekannt ist, erlaubt es uns eine vollständige und exakte Klassifizierung und Interpretation der Teilchenpaarverteilungen in 1d.

Q 57.32 Thu 16:30 P1

Quantum dynamics in the bosonic Josephson junction — •Moritz Hiller[1], Maya Chuchem[2], Katrina Smith-Mannschott[3,4], Tsampikos Kottos[3], Amichay Vardi[5,6], and Doron Cohen[2] — [1]Physikalisches Institut, Albert-Ludwigs-Universität Freiburg, Hermann-Herder-Str. 3, 79104 Freiburg — [2]Department of Physics, Ben-Gurion University of the Negev, P.O.B. 653, Beer-Sheva 84105, Israel — [3]Department of Physics, Wesleyan University, Middletown, Connecticut 06459, USA — [4]MPI für Dynamik und Selbstorganisation, Bunsenstraße 10, 37073 Göttingen — [5]Department of Chemistry, Ben-Gurion University of the Negev, P.O.B. 653, Beer-Sheva 84105, Israel — [6]ITAMP, Harvard-Smithsonian CFA, 60 Garden St., Cambridge, Massachusetts 02138, USA

We employ a semiclassical picture to study dynamics in a bosonic Josephson junction with various initial conditions [1]. Phase-diffusion of coherent preparations in the Josephson regime is shown to depend on the initial relative phase between the two condensates. For initially incoherent condensates, we find a universal value for the buildup of coherence in the Josephson regime. In addition, we contrast two seemingly similar on-separatrix coherent preparations, finding striking differences in their convergence to classicality as the number of particles increases.

[1] M. Chuchem *et al.*, Phys. Rev. A **82**, 053617 (2010)

Q 57.33 Thu 16:30 P1

Spectral origin of decaying Bloch oscillations — •Hannah Venzl, Moritz Hiller, and Andreas Buchleitner — Physikalisches Institut, Albert-Ludwigs-Universität Freiburg, Hermann-Herder-Str. 3, 79104 Freiburg

We study Bloch oscillations of ultracold bosonic atoms in tilted optical lattices. Our analysis is based on the Bose-Hubbard Hamiltonian amended by a static field term. For comparable values of the control parameters, namely the inter-atomic interaction, the tunneling coupling, and the static field, the system displays chaotic level statistics. In this regime, the Bloch oscillations exhibit an irreversible and fast decay. We show that the corresponding decay rate can be obtained from the spectral properties of the Hamiltonian by investigating the weighted distribution of frequencies appearing in the local density of states.

Q 57.34 Thu 16:30 P1

Realization of Tunable Tunneling Dynamics and New Phases in Triangular Optical Lattices — •Christoph Ölschläger, Julian Struck, Christina Staarmann, Parvis Soltan-Panahi, Rodolphe Le Targat, Patrick Windpassinger, and Klaus Sengstock — Institut für Laser-Physik, Universität Hamburg, 22761 Hamburg, Germany

Ultracold quantum gases in optical lattices are well suited to investigate and simulate systems known from other physical branches.

Here we report on the simulation of new non-ferromagnetic phases of spinless bosons in triangular lattices that can be described in analogy to magnetism in solid state physics. The additional degree of freedom in our system is the possibility to change the order and sign of the tunneling matrix elements between adjacent lattice sites. An independent control of the various tunneling parameters is achieved by a fast elliptical lattice acceleration. This is induced by frequency modulations of the lattice beams where the well adjustable modulation amplitudes determine the resulting tunneling dynamics.

First experimental observations and analysis of the different phases in the weakly interacting regime are presented. The excellent agreement between theoretical predictions (Eckardt et al. [1]) and the observed phases is promising to explore the strongly interacting regime and associated new quantum phases like a spin-liquid.

[1] A. Eckardt et al., EPL 89, 10010 (2010)

Q 57.35 Thu 16:30 P1

Local mean field in optical lattices — •Astrid E. Niederle and Heiko Rieger — Universität des Saarlandes, Germany

The properties of a Bose-Einstein condensate in an optical lattice are under investigation here and studied using local mean-field theory [2]: By definition of the so called superfluid order parameter, the high dimensional Hamiltonian describing the system can be decomposed in a sum of on-site Hamiltonians. This on-site Hamiltonian forms the starting point for our investigations, in order to investigate the system in different dimensions and various geometries. Through a detailed study of the groundstate properties we observe the competing phases. The Mott lobes separate the insulating from the superfluid phase and in the presence of disorder [1] the Bose glass appears in between. Moreover this investigations in local mean-field theory can be carefully expanded to the hole spectrum in order to study time dependent effects.

[1] J. Kisker and H. Rieger, Phys. Rev. B 55, 11981 (1997)
[2] P. Buonsante, A. Vezzani, Phys. Rev. A 70, 033608 (2004)

Q 57.36 Thu 16:30 P1

Effective occupation-dependent tunneling in optical lattices — •Maria Langbecker, Ole Jürgensen, Dirk-Sören Lühmann, and Klaus Sengstock — Institut für Laser-Physik, Universität Hamburg, 22761 Hamburg, Germany

Usually, atoms in optical lattices are described by single-band Hubbard models. The admixture of higher bands caused by interactions leads to non-negligible changes of the tunneling matrix elements. As a consequence the tunneling process becomes explicitly occupation-dependent which gives rise to an effective Hubbard Hamiltonian and novel exciting quantum phases.

We calculate the effective tunneling in optical lattices using a mean-field approach solely dependent on the occupation number of higher orbitals. This simple effective picture already gives results that compare well with the fully correlated treatment and visualizes intuitively the impact of higher-band tunneling processes. Even for few particles per lattice site, the effective tunneling differs notably from the single-band tunneling for both purely bosonic systems and boson-fermion mixtures.

The results demonstrate, in general, the important role of higher-band processes in optical lattices.

Q 57.37 Thu 16:30 P1

Quantum Many-Body Systems on the Single-Atom Level — •P. Schauss, C. Weitenberg, M. Endres, J. F. Sherson, M. Cheneau, T. Fukuhara, I. Bloch, and S. Kuhr — Max- Planck-Institut für Quantenoptik, Hans-Kopfermann-Str. 1, D-85748 Garching

Investigations of ultracold quantum gases in optical lattices have so far been mostly restricted to access global information of the system. Here we present a detection technique that enables us to measure the local distribution of the particles on a single-site and single-atom level[1].

Using a high resolution objective we observed fluorescence images of bosonic Mott insulators in the atomic limit. We reconstructed the atom distribution on the lattice from our images and identified individual excitations with high fidelity. A comparison of the radial density and variance distributions with theory provides a precise in situ temperature and entropy measurement from single images.

Furthermore we will present progress towards in-situ thermometry and the direct measurement of correlations across the superfluid-to-Mott-insulator transition.

[1] J. Sherson et al., Nature 467, 68 (2010).

Q 57.38 Thu 16:30 P1

Detection of the Amplitude Mode in a Strongly Interacting Superfluid by Bragg Spectroscopy — •Sören Götze, Jannes Heinze, Jasper Simon Krauser, Bastian Hundt, Nick Fläschner, Christoph Becker, and Klaus Sengstock — Institut für Laser-Physik, Universität Hamburg

By the creation of ultracold quantum gases in optical lattices, superfluidity can be studied over a wide range of tunable parameters, including the regime of strong correlations. However, for an in-depth understanding of the system's excitational structure, especially in the strongly correlated regime, new methods of detection and analysis are required [1]. We report on the first dedicated investigation of the recently proposed amplitude mode using Bragg spectroscopy on a strongly interacting BEC in a 3D optical lattice. We compare our data with a spatially resolved, time-dependent dynamic Gutzwiller calculation and thereby clearly identify the underlying mode structure, including systematic shifts of the resonances, e.g. due to the backaction of the Bragg beams and beyond linear response effects [2].

[1] P. T. Ernst et al., Probing superfluids in optical lattices by momentum-resolved Bragg spectroscopy, Nature Physics advance online publication, 29.11.2009 (DOI: 10.1038/nphys1476)

[2] U. Bissbort et al., Detecting the Amplitude Mode of Strongly Interacting Lattice Bosons by Bragg Scattering, arXiv:1010.2205

Q 57.39 Thu 16:30 P1

Probing ultracold fermions in optical lattices — •Jasper Simon Krauser, Sören Götze, Jannes Heinze, Bastian Hundt, Nick Fläschner, Dirk-Sören Lühmann, Christoph Becker, and Klaus Sengstock — Institut für Laserphysik, Universität Hamburg

Quantum gases in optical lattices offer a wide range of applications for quantum simulation due to fully tunable lattice and atomic interaction parameters. In our setup we sympathetically cool ^{87}Rb and ^{40}K and load this mixture into an optical lattice superimposed with a magic dipole trap. In this poster, we discuss experimental aspects and recent results of our Bose-Fermi mixture project. In detail, we report on high resolution spectroscopy of ultracold fermions in optical lattices with full momentum resolution. We can accurately extract the band structure and filling information allowing for the determination of the phase of the system. Our experimental sensitivity is promising for the extension of these studies to observe interaction shifts due to the presence of bosonic atoms [1,2] as well as changes in the density of states for interacting fermionic gases.

[1] Lühmann et al., PRL 101, 050402 (2008)

[2] Best et al., PRL 102, 030408 (2009)

Q 57.40 Thu 16:30 P1

Interacting Fermions in Optical Lattices - Exploring the Fermi-Hubbard Hamiltonian — •Jens Philipp Ronzheimer[1], Lucia Hackermüller[2], Simon Braun[1], Michael Schreiber[1], Tim Rom[1], Sebastian Will[1], Thorsten Best[3], Ulrich Schneider[1], and Immanuel Bloch[1] — [1]LMU München & MPQ Garching — [2]U Nottingham — [3]ALU Freiburg

Fermions in optical lattices can constitute an ideal and defect-free implementation of the Fermi-Hubbard Hamiltonian. While being more accessible to measurements than condensed matter systems, they allow at the same time for the direct manipulation of all relevant parameters.

We report on experiments with a two-component ultracold Fermi gas of ^{40}K atoms in a blue detuned lattice. Previous experiments regarding equilibrium states of the Fermi-Hubbard Hamiltonian as well as results on the dynamics of out-of-equilibrium states in the homogeneous Hubbard model are presented.

The experimental setup allows for a variety of experiments with Bose-Fermi and Fermi-Fermi mixtures in optical lattices in 1,2 and 3 dimensions. Employing a red detuned Dipole trap and a blue detuned lattice at tunable wavelength, we are able to adjust every parameter of the respective Hamiltonians individually. The experimental setup has been rebuilt after moving to the LMU in Munich and we present the improved parameters as well as an analysis of current challenges and ways to overcome them.

Q 57.41 Thu 16:30 P1

Novel Preparation Schemes for Hexagonal Lattices — •Christina Staarmann, Parvis Soltan-Panahi, Julian Struck, Christoph Ölschläger, Dirk-Sören Lühmann, Rodolphe Le Targat, Patrick Windpassinger, and Klaus Sengstock — Institut für Laser-Physik, Universität Hamburg, Luruper Chaussee 149, 22761 Hamburg, Germany

We have recently realized a spin-dependent hexagonal lattice, which imposes an intrinsic magnetic ordering on the atoms [1]. In this way, it is possible to uniquely study interaction effects between different spin-states leading to novel quantum phases such as the realization of an interaction induced mixing of the s- and p-band states in the superfluid regime. Another interesting aspect of the hexagonal lattice geometry is its linear – Dirac-particle like – dispersion relation at the vicinity of the so-called Dirac cones which can even be explored in case of an ultracold cloud of bosonic atoms, such as ^{87}Rb.

Here, we present a novel experimental preparation scheme, which allows for an in-situ manipulation of the spin-dependent potential. This is achieved by a controlled change of the magnetic quantization axis of the system. In this way it is also possible to continuously tune the band-gap at the Dirac cone, offering an important prerequisite to study Dirac-like physics with ultracold atoms.

[1] Multi-Component Quantum Gases in Spin-Dependent Hexagonal Lattices: P. Soltan-Panahi, J. Struck, P. Hauke, A. Bick, W. Plenkers, G. Meineke, C. Becker, P. Windpassinger, M. Lewenstein, K. Sengstock, Preprint: arXiv:1005.1276 (2010)

Q 57.42 Thu 16:30 P1

Interacting Bose-Fermi Mixtures in Optical Lattices — •Simon Braun[1], Sebastian Will[1], Thorsten Best[2], Philipp Ronzheimer[1], Michael Schreiber[1], Tim Rom[1], Ulrich Schneider[1], Dirk-Sören Lühmann[3], and Immanuel Bloch[1] — [1]Ludwig-Maximilians-Universität München — [2]Albert-Ludwigs Universität Freiburg — [3]Universität Hamburg

Mixtures of ultracold quantum gases in optical lattices form novel quantum many-body systems, whose properties are governed by an intriguing interplay of quantum statistics, inter- and intraspecies interactions, as well as the relative atom numbers of the constituents.

In our setup, we cool bosonic ^{87}Rb and fermionic ^{40}K to simultaneous quantum degeneracy. We realize a Bose-Fermi Hubbard model by loading the atoms into the combined potential of a blue-detuned three-dimensional optical lattice and a red-detuned dipole trap. Interspecies interactions are controlled using Feshbach resonances and Raman transitions between different Zeeman sublevels.

Our investigations of the many-body properties of an attractively interacting Bose-Fermi mixture revealed a marked shift in the superfluid to Mott insulator transition due to selftrapping. By studying the quantum collapse and revival dynamics of the bosonic component in the 3D optical lattice, we were able to measure the Bose-Bose and Bose-Fermi interaction energies with high precision and revealed a modification of Bose-Bose interactions induced by an interacting fermion.

Finally, we present improvements to the experimental apparatus implemented after relocation to Munich.

Q 57.43 Thu 16:30 P1

The Dicke quantum phase transition in an optical cavity QED system — •Rafael Mottl[1], Kristian Baumann[1], Ferdinand Brennecke[1], Tobias Donner[1], Christine Guerlin[2], and Tilman Esslinger[1] — [1]Institute for Quantum Electronics, ETH Zurich, 8093 Zurich, Switzerland — [2]Thales Research and Technology, 91767 Palaiseau Cedex, France

The Dicke model describes the collective interaction between an ensemble of two-level atoms and a single electromagnetic field mode, and remains a fundamental theme in quantum optics. In the thermodynamic limit this system was predicted to undergo a quantum phase transition from a normal to a superradiant phase. We have achieved its first experimental realization in an open system in which a Bose-Einstein condensate is loaded into an optical high-finesse cavity. The superfluid atoms collectively couple a far-detuned pump field to the empty cavity mode. Above a critical pump power the atoms self-organize into an emergent checkerboard pattern which shows supersolid character. The boundary of this novel phase was mapped out and coincides with its theoretical description by the Dicke model. Investigating the excitation spectrum below threshold by Bragg spectroscopy, we could identify a vanishing energy gap when approaching the critical point - a precursor of the quantum phase transition.

Q 57.44 Thu 16:30 P1

Experiments with ultracold atoms in optical superlattices — •Monika Aidelsburger[1], Marcos Atala[1,2], Yu-Ao Chen[1,2], Sylvain Nascimbène[1,2], Stefan Trotzky[1], and Immanuel Bloch[1,2] — [1]Fakultät für Physik Ludwig-Maximilians-Universität, 80799 München, Deutschland — [2]Max-Planck-Institut für Quantenoptik, 85748 Garching, Deutschland

Optical lattices became an essential tool for simulating condensed matter physics with ultracold atoms. By adding a standing wave with twice the periodicity to one of the three axis of a simple cubic lattice we can create a three-dimensional array of isolated double wells. We would like to present our recent experiments done in this configuration and discuss the extension of the current system to a two-dimensional superlattice. This will enable us to investigate minimum forms of topologically ordered quantum states in isolated plaquettes, such as Resonating Valence Bond states and to study ring exchange interactions, the basic ingredient of lattice gauge theories.

Q 57.45 Thu 16:30 P1

Non-Equilibrium Phase Transition of Ultracold Bosons in an Optical Lattice Coupled to a BEC Reservoir — •Mathias Hayn[1] and Axel Pelster[2] — [1]Institut für Theoretische Physik, Freie Universität Berlin, Arnimallee 14, 14195 Berlin, Germany — [2]Fachbereich Physik, Universität Duisburg-Essen, Lotharstrasse 1, 47048 Duisburg, Germany

Recently, a promising quantum optical realization for a driven-dissipative many-body system of bosons in a lattice was proposed [1], in which the competition of unitary Hamiltonian and dissipative Liouvillian dynamics leads to a non-equilibrium phase transition [2]. At first, we give a detailed derivation of this model, based on microscopic Hamiltonians for both bosons in an optical lattice and for a bath in form of a weakly interacting Bose gas. We obtain the result that the dynamics of the bosons in the optical lattice can be described by a master equation in Linblad form, with the dissipative coupling being non-zero only in one dimension. Afterwards, we convert the master equation into a hierarchy of moment equations, which is approximately solved. In the limit of small particle densities we are able to determine, in accordance with the findings of Ref. [2], the order parameter as well as the critical interaction strength, which characterise the onset of a non-equilibrium phase transition from a thermal to a superfluid state.

[1] S. Diehl, A. Micheli, A. Kantian, B. Kraus, H.P. Büchler, and P. Zoller, Nature Phys. **4**, 878 (2008).
[2] S. Diehl, A. Tomadin, A. Micheli, R. Fazio, and P. Zoller, Phys. Rev. Lett. **105**, 015702 (2010).

Q 57.46 Thu 16:30 P1

Quest for anisotropic solitons in dipolar Bose-Einstein condensates — •Patrick Köberle, Rüdiger Eichler, Jörg Main, and Günter Wunner — 1. Institut für Theoretische Physik, Uni Stuttgart

Quasi-two-dimensional bright solitons have been predicted to exist in dipolar Bose-Einstein condensates [1]. Yet, an experimental proof is still lacking. We first present calculations to mark the stability regions for experimentally relevant parameters. We then show the results of simulations of a planned experiment. They demonstrate how solitons can be created dynamically and reveal that this is still possible if some noise is added to the scattering length. This is of special importance because noise is always present in the experiment and could potentially destroy the soliton.

I. Tikhonenkov, B. A. Malomed, and A. Vardi, Phys. Rev. Lett. **100**, 090406 (2008)

Q 57.47 Thu 16:30 P1

General Relativistic Description of Bose-Einstein Condensates — •Oliver Gabel and Reinhold Walser — Institut für Angewandte Physik, Technische Universität Darmstadt, Hochschulstr. 4a, 64289 Darmstadt

Releasing Bose-Einstein condensates from traps is the standard way to observe the state of the system by *time-of-flight* measurements. This free fall is usually limited by the size of the vacuum chamber and is too short to study gravitational physics questions. With the realization of the QUANTUS experiment [1], it has become possible to perform free-fall experiments over large distances of 100 m and long times of 5–10 seconds. After detailed modeling of the Newtonian evolution of the release [2], it becomes relevant to quantify the expected relativistic corrections.

In this contribution, we present first results on the way towards a general relativistic description of free-falling and Earth-bound Bose-Einstein condensates.

[1] T. van Zoest et. Al., *Bose-Einstein Condensation in Microgravity*, Science, **328**, 1540 (2010).
[2] G. Nandi, R. Walser, E. Kajari, and W. P. Schleich, *Dropping cold quantum gases on Earth over long times and large distances*, Phys. Rev. A **76**, 63617 (2007).

Q 57.48 Thu 16:30 P1

Semiclassical dynamics of self-organization of atoms in optical cavities — •Stefan Schütz[1], Hessam Habibian[2], and Giovanna Morigi[1] — [1]Theoretische Physik, Universität des Saarlandes, D-66041 Saarbrücken, Germany — [2]Departament de Física, Universitat Autònoma de Barcelona, E-08193 Bellaterra, Spain

We theoretically study the formation of self-organized structures of atoms, whose dipolar transition is driven by a laser and also couples to the optical mode of a high-finesse cavity. Self-organization in the cavity field emerges due to the mechanical forces of the cavity photons on the atoms, whereby the cavity field is sustained by the photons scattered by the atoms from the laser and hence depends on the atomic position. The analysis is based on a model, in which the coupled cavity field and atomic dynamics are evaluated by numerically solving the Heisenberg-Langevin equation in the semiclassical limit, namely, when the number of cavity photons is much larger than unity and the atomic momentum is much larger than the photon recoil [1]. Noise sources are here diffusion due to spontaneous decay and photon losses via the resonator. We study the onset of selforganization, focussing in particular on the patterns obtained, when the atoms belong to different species.

[1] P. Domokos *et al.*, J. Phys. B: At. Mol. Opt. Phys. **34** 187-198 (2001)

Q 57.49 Thu 16:30 P1

Ring structures in linear multipole ion traps — •Florian Cartarius, Cecilia Cormick, and Giovanna Morigi — Theoretische Physik, Universität des Saarlandes, 66041 Saarbrücken, Germany

Doppler cooled ions in linear radiofrequency multipole traps [1] can organize in ordered structures. The equilibrium positions of the ions result from the balance between the mutual Coulomb repulsion and the external trapping potential. If the confinement along the axial direction of the trap is much tighter than along the transverse directions, the ions can form ring-shaped structures. In this work, we theoretically analyse the equilibrium configurations of dozens of ions in anisotropic traps for different orders of the multipolar potential. In particular, we identify parameter regimes where the one-ring arrangement is stable, and study the collective motional modes.

[1] D. Douglas, A. Frank, and D. Mao, Mass Spectrom. Rev. 24, 1-29 (2005)

Q 57.50 Thu 16:30 P1

Experiments with laser-cooled atoms trapped in the evanescent field surrounding an optical nanofiber — •Daniel Reitz[1], Rudolf Mitsch[1], Melanie Müller[1], Samuel T. Dawkins[2], and Arno Rauschenbeutel[1] — [1]Technische Universität Wien - Atominstitut, Stadionallee 2, A-1020 Wien — [2]Johannes Gutenberg-Universität Mainz, AG QUANTUM, 55099 Mainz, Germany

We present recent results of experiments with Cs-atoms in our nanofiber-based optical dipole trap. The atoms are trapped in a 1d optical lattice formed by a two color-evanescent field sourrounding the optical nanofiber. Atoms inside the trap are detected by measuring the transmission of a weak probe beam, launched through the fiber. At resonance, each atom absorbs about one percent of the probe via evanescent field coupling, yielding a high optical density of up to 39 for about 2000 trapped atoms. Adding a second light field in the fiber allows us to coherently prepare the atomic ensemble. First results of measurements of the Autler Townes Effect as well as first observations of electromagnetically induced transparency are presented. Finally, in the dispersive regime, the interaction-induced phase shift experienced by the probe is measured, providing us with additional information. We show that by using this method, the lifetime of the atoms in our trap can be measured non-destructively. Our work opens the route towards the realization of hybrid quantum systems that combine atoms with, e.g., solid state quantum devices and towards non-linear optics applications. Financial support by the Volkswagen Foundation, the ESF and the FWF (CoQuS) is gratefully acknowledged.

Q 57.51 Thu 16:30 P1

Control of refractive index and motion of a single atom by quantum interference — •René Reimann[1], Wolfgang Alt[1], Stefan Brakhane[1], Martin Eckstein[1,2], Tobias Kampschulte[1], Miguel Martinez-Dorantes[1], Artur Widera[1,3], and Dieter Meschede[1] — [1]Institut für Angewandte Physik der Universität Bonn, Wegelerstr. 8, 53115 Bonn — [2]Max-Born-Institut, Abteilung A2, Max-Born-Str. 2 A, 12489 Berlin — [3]Fachbereich Physik der TU Kaiserslautern, Erwin-Schrödinger-Str., 67663 Kaiserslautern

The properties of an optically probed atomic medium can be changed dramatically by coherent interaction with a near-resonant control light field. We will present our experimental results on the elementary case of electromagnetically induced transparency (EIT) with a single neutral atom inside an optical cavity probed by a weak field [1]. We have observed modification of the dispersive and absorptive properties of a single atom by changing the frequency of the control light field in the off-resonant regime.

In this regime, the creation of a transparency window close to a narrow absorption peak can give rise to a sub-Doppler cooling mechanism. We have observed strong cooling and heating effects in the vicinity of the two-photon resonance. The cooling increases the storage time of our atoms twenty-fold to about 16 seconds. Recent investigations of this effect outside the cavity using microwave sideband spectroscopy have revealed that a large fraction of atoms is cooled to the axial ground state of the trap.

[1] T. Kampschulte *et al.*, Phys. Rev. Lett. **105**, 153603 (2010)

Q 57.52 Thu 16:30 P1

Phase space compression with an accelerated diode and mirror potential — •Sönke Schmidt[1], J. Gonzalo Muga[2], and Andreas Ruschhaupt[1] — [1]Institut für Theoretische Physik, LU Hannover, Germany — [2]Departamento de Química Física, UPV-EHU, Bilbao, Spain

We propose a scheme to cool atoms by collision with an accelerated potential. To achieve phase space compression we combine this with an irreversible diodic device. An incoming beam of atoms can pass this diode only in one direction and thus becomes trapped between the diode and the potential. Furthermore it gets slowed due to subsequent collisions with both the moving potential and the diode. We show both analytical and numerical results and compare it to other schemes.

Q 57.53 Thu 16:30 P1

A compact modular 2D-MOT setup — Bastian Höltkemeier, Christoph Hofmann, Simone Götz, •Hannes Busche, and Matthias Weidemüller — Physikalisches Institut, Universität Heidelberg, Philosophenweg 12, 69120 Heidelberg

We present a compact modular source for ultracold rubidium atoms based on the 2D-MOT design first demonstrated in [1]. Aiming for maximal compactness and minimal weight of the setup, a specially designed optics module generates three adjacent cigarshaped cooling regions that allow for two-dimensional atom cooling. By means of two imbalanced counterpropagating pushing beams, a so-called 2D$^+$-configuration is realized. Inspired by [2], the optics module also features a set of permanent bar magnets to generate a two-dimensional magnetic quadrupole field. Using positioning pins, the optics module can easily be attached to or removed from the UHV glass cell. This allows external alignment and facilitates the assembly of the 2D-MOT. So far, two modules are implemented in our Rydberg experiment and our transportable MOTRIMS experiment. In general, the design could be adapted to other alkali atoms, except lithium.

[1] K. Dieckmann et al., Phys. Rev. A 58, 3891 (1998)
[2] T. G. Tiecke et al., Phys. Rev. A 80, 013409 (2009)

Q 57.54 Thu 16:30 P1

Vibrational ground state cooling of a neutral atom in a tightly focused optical dipole trap. — •Syed Abdullah Aljunid[1], JianWei Lee[1], Martin Paesold[2], Brenda Chng[1], Gleb Maslennikov[1], and Christian Kurtsiefer[1] — [1]Centre for Quantum Technologies / Dept. of Physics, National University of Singapore — [2]ETH, Zurich

Recent experiments have shown that an efficient interaction between a single trapped atom and light can be established by concentrating light field at the location of the atom by focusing [1-3]. However, to fully exploit the benefits of strong focusing one has to pinpoint the atom at the maximum of the field strength. The position uncertainty due to residual kinetic energy of the atom in the dipole trap (depth $\sim 1\,\mathrm{mK}$) after molasses cooling is significant (few 100 nm) already for moderate focusing strength [2]. To address this problem we implement a Raman Sideband cooling technique, similar to the one commonly used in ion traps [4], to cool a single ^{87}Rb atom to the ground state of the trap. We have cooled the atom along the transverse trap axis (trap frequency $\nu_\tau = 55\,\mathrm{kHz}$), to a mean vibratonal state $\bar{n}_\tau = 0.55$ and investigate the impact on atom-light interfaces.

[1] M. K. Tey, et al., Nature Physics **4** 924 (2008)
[2] M. K. Tey et. al., New J. Phys. **11**, 043011 (2009)
[3] S.A. Aljunid et al., Phys. Rev. Lett. **103**, 153601 (2009)
[4] C. Monroe et al., Phys. Rev. Lett. **75**, 4011 (1995)

Q 57.55 Thu 16:30 P1

A New Setup for Probing Bose-Fermi Mixtures in Optical Lattices — •Tracy Li[1], Lucia Duca[1], Martin Boll[1], Jens Phillip Ronzheimer[1], Ulrich Schneider[1], and Immanuel Bloch[1,2] — [1]Fakultät für Physik, Ludwig-Maximilians-Universität, 80799 München, Germany — [2]Max-Planck-Institut für Quantenoptik, 85748 Garching, Germany

Degenerate Bose-Fermi mixtures consist of different atomic species with different quantum-statistics. The interactions between these particles can give rise to a rich variety of effects such as novel quantum phases or polaron physics. In particular, by trapping Bose-Fermi mixtures in optical lattices, we can create a controlled and versatile model system for probing condensed-matter phenomena.

In the experiment, the atoms will be lasercooled using a combination of a 2D+ [1] and 3D magneto-optical traps (MOTs). We present and characterize a new design for a 2D+MOT of ^{87}Rb and ^{40}K. The 2D+MOT generates a collimated, continuous beam of atoms for more efficient loading into the two-species 3D MOT. After the MOTs, the mixture is magnetically transported into a glass cell, where sympathetic and evaporative cooling to simultaneous quantum degeneracy occur first in a plugged quadrupole trap and then in a crossed dipole trap. We present the current status of this experiment.

[1] Dieckmann et.al., PRA 58, 3891 (1998).

Q 57.56 Thu 16:30 P1

Trap loss in a double species MOT of Yb and Rb — •Maximilian Madalinski, Cristian Bruni, Frank Münchow, and Axel Görlitz — Institut für Experimentalphysik, HHU Düsseldorf, 40225 Düsseldorf

Ultracold mixtures of two atomic species are an excellent environment to study their interspecies collisions, to produce exotic heteronuclear molecules or to study double species quantum gases. In our experiment we are able to trap seperately 10^9 Rb and 10^7 Yb atoms but we observe a strong loss of Yb in the combined MOT. The Yb MOT uses the $^1S_0$ to $^3P_1$ intercombination transition at 555.8 nm. The production of excited molecules was already achieved in this configuration. Here we present a method of determining the trap loss coefficients of Yb through Rb in our combined trap. Since Yb has trapable bosonic and fermionic isotopes collisions in every combination can be explored.

Q 57.57 Thu 16:30 P1

Segmentierte Oberflächenfalle mit integriertem Magnetfeldgradienten — •Peter Kunert und Christof Wunderlich — Fachbereich Physik, Universität Siegen, 57068 Siegen, Deutschland

Ein erfolgversprechender Ansatz, um Ionenfallen auf kleine Dimensionen zu skalieren und somit zu Arrays erweiterbar zu machen, liegt in der Entwicklung von Oberflächenfallen. Bei diesen Fallen wird durch geschicktes Anlegen von Radiofrequenz- und DC-Spannungen an planaren Elektroden eine Potentialtiefe der Größenordung 0,1 eV zum Einfangen von Ionen erzeugt. Mittels segmentierten DC-Elektroden können die eingefangenen Ionen in der Falle transportiert werden. Dank bekannter Herstellungsmethoden aus der Mikrosystemtechnik (Lithographie, Galvanik) ist die Produktion dieser Fallen zeit- und kostengünstig. Darüberhinaus lassen sich auf den Fallenchips sowohl Leiterbahnen zur Erzeugung von Magnetfeldgradienten am Ort der Ionen als auch Mikrowellenleiter integrieren.

Die Simulationen verschiedener Fallengeometrien werden vorgestellt und analysiert. Verschiedene Ansätze zur Realisierung von Magnetfeldgradienten am Ort der Teilchen werden diskutiert. Die Herstellung eines Fallenchips wird erläutert. Der Aufbau des Experimentes wird präsentiert.

Q 57.58 Thu 16:30 P1

Microwave guiding of electrons in a planar Paul trap — •Roman Fröhlich, Johannes Hoffrogge, Jakob Hammer, and Peter Hommelhoff — Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Straße 1, 85748 Garching bei München

We present an experiment demonstrating the guiding of electrons in a linear Paul trap [1]. The trapping potential is generated by a microstructured planar electrode geometry. The trap is driven at frequencies of around 1 GHz, leading to trap frequencies of about 150 MHz. In comparison to the confinement of ions much higher driving frequencies are necessary because of the higher charge to mass ratio of electrons. We show that guiding works over a range of electron energies from 1eV to 5eV and characterize the effect of substrate charging on the guiding properties. We also investigated the effect of trap stability and depth over a wide range of driving frequencies and voltages. Furthermore we present second generation substrates with high aspect ratio and more complex trap electrode structures, fabricated by thick film lithography. This includes beam splitters and electrically long structures. These devices together with coherent electron emitters like single atom tips may enable applications such as guided electron interferometry.

[1] J. Hoffrogge, R. Fröhlich and P. Hommelhoff - submitted (2010)

Q 57.59 Thu 16:30 P1

Towards sequential BEC production with high repetition rates on a mesoscopic wire structure — Stefan Jöllenbeck[1], •Jan Mahnke[1], Richard Randoll[1], Manuela Hanke[1], Ilka Geisel[1], Wolfgang Ertmer[1], Jan Arlt[2], and Carsten Klempt[1] — [1]Institut für Quantenoptik, Leibniz Universität Hannover — [2]Department of Physics and Astronomy, Aarhus University

The sensitivity of atom interferometers could be increased by using quantum degenerate input states. To gain the advantage of a higher resolution would require a source providing sufficiently large ensembles as well as high repetition rates. While conventional BEC experiments do not reach the required repetition rates, microscopic atom chips may enhance cooling rates. However, atom chips typically capture significantly smaller ensembles. Our aim is to combine the advantages of both types of experiments by using a mesoscopic wire structure to provide the magnetic fields for magneto-optical and magnetic trapping.

Fast sequential BEC production will be achieved by consecutive loading of magneto-optical traps. The captured atoms are subsequently transferred to a shielded vacuum region on a magnetic conveyor belt. By parallel evaporation of several clouds during the transport, high BEC repetition rates of more than 2 Hz will be achievable.

We present our latest results of loading and transporting atoms in our magnetic conveyor belt.

Q 57.60 Thu 16:30 P1

Manipulation of small atom clouds in a microscopic dipole trap — •Andreas Fuhrmanek, Ronan Bourgain, Yvan Sortais, Philippe Grangier, and Antoine Browaeys — Institut d'Optique, RD 128 Campus Polytechnique, 91127 Palaiseau Cedex, France

Recent years have seen a growing interest in the study of small, but dense cold atomic ensembles. Here we present our progress on the manipulation of cold atomic clouds in a regime where they contain only a few tens of atoms. In our case we use 87Rb atoms, trapped in a microscopic optical dipole trap, to study this mesoscopic regime. We use a single atom to measure the resolution of our imaging system. This method provides a calibration of our detection scheme which is useful to understand the regime where many atoms are trapped. We also implement an atom counting method that is capable of reconstructing the atom number distribution inside the dipole trap and allows a acurate measurement of the average atom number. With these techniques in hand we perform measurements on the dipole trap losses in the presence of near resonant light. The results help to understand the mechanisms of subpoissonian dipole trap loading and should be useful for the realisation of a BEC with a few atoms only.

Q 57.61 Thu 16:30 P1

Feedback control of the hyperfine ground states of neutral atoms in an optical cavity — •Miguel Martinez-Dorantes[1], Wolfgang Alt[1], Stefan Brakhane[1], Tobias Kampschulte[1], René Reimann[1], Artur Widera[1,2], and Dieter Meschede[1] — [1]Institut für Angewandte Physik der Universität Bonn, Wegelerstr. 8, 53115 Bonn — [2]Fachbereich Physik der TU Kaiserslautern, Erwin-Schrödinger-Str., 67663 Kaiserslautern

Detection and manipulation of atomic spin states is essential for many experimental realizations of quantum gates. Feedback schemes to stabilize the states and their superpositions can counteract perturbations caused by the environment.

In our experiment we deduce the atomic spin state of one or two Caesium atoms by measuring the transmission of a probe laser through a high-finesse cavity. Depending on the number of atoms in the hyperfine state that strongly couples to the cavity, the resonance of the cavity is shifted and the probe laser transmission is decreased. We employ a Bayesian update formalism to obtain time-dependent probabilities for the atomic states of one and two atoms [1].

We will present an experimental implementation using a digital signal processor which allows us to determine the atomic spin state in real-time. First experimental results of an extension to a feedback loop for the preparation and stabilization of atomic states will be shown.

[1] S. Reick, K. Mølmer *et al.*, J. Opt. Soc. Am. B **27**, A152 (2010)

Q 57.62 Thu 16:30 P1

Single-atom-resolved spin manipulation in a Mott insulator — •T. Fukuhara, C. Weitenberg, M. Endres, J. F. Sherson, M. Cheneau, P. Schauss, I. Bloch, and S. Kuhr — Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Str. 1, D-85748 Garching

Ultracold atoms have attracted a lot of interest due to the excellent controllability of parameters. Extending this control down to single lattice sites is a long-standing quest in the field. Here we report on single-site-resolved spin manipulation in an atomic Mott insulator. A combination of a differential light shift caused by a tightly focused laser beam and a microwave sweep allowed us to flip the spin of selected atoms and to create arbitrary two-dimensional spin patterns starting from a Mott insulator with unity filling. To investigate the effect of our scheme on the motional state of the atoms, we directly observed the coherent tunneling dynamics of single atoms after addressing and found that most of the atoms remained in the motional ground state. Our technique opens new perspectives in a wide range of novel applications from quantum dynamics of spin impurities, entropy transport, implementation of novel cooling schemes, and engineering of quantum many-body phases to quantum information processing.

Q 57.63 Thu 16:30 P1

Hochstabiler Frequenzstabilitätstransfer — •Dave Brauns, Matthias Wolke, Julian Klinner und Andreas Hemmerich — Universität Hamburg, Hamburg, Deutschland

Im Rahmen von Experimenten der Optomechanik mit einem Bose-Einstein-Kondensat in einer Mode eines Hochfinesse-Resonators ist ein hochstabiler Frequenzstabilitätstransfer nötig. Hierzu werden mittels Pound-Drever-Hall-Regelung zwei Laser mit einer Wellenlängendifferenz von mehreren 10 Nanometern auf einen Resonator mit einer Linienbreite von nur 4 kHz stabilisiert. Im nächsten Schritt werden die beiden Laser mit festem Frequenzabstand synchron mittels einer AOM-Regelung auf den Experimentresonator (Linienbreite ca. 20kHz) frequenzstabilisiert. Durch diese Regelungskette wird ein schmalbandiger Experimentierlaser bei einer nahezu beliebigen Frequenz relativ zur Resonatorresonanz zur Verfügung gestellt.

Q 57.64 Thu 16:30 P1

Many-body effects in Rydberg gases — •Martin Gärttner[1], Jörg Evers[1], and Thomas Gasenzer[2] — [1]MPI für Kernphysik, Heidelberg — [2]Institut für theoretische Physik, Heidelberg

The early theoretical treatmet of ensembles of Rydberg atoms fucused on mean field models, which explain the observed Rydberg blockade well, but disregard all quantum many-body features of the system. It has been shown recently [1,2,3] that these microscopic many-body features are important, especially at high atom densities.

We investigate the dynamics of cold interacting Rydberg gases taking into account the full many body Hamiltonian. For small atom numbers we perform fully coherent exact many body simulations. The parameter space is explored for certain toy models with a focus on higher order correlations. More realistic situations with larger atom numbers and decoherence effects are treated by Monte Carlo sampling. Here we make use of the assumption of the Rydberg blockade to reduce the number of basis states of our otherwise tremendously large Hilbert space.

[1] T. Pohl and P. R. Bermann, Phys. Rev. Lett. 102, 013004 (2009)
[2] B. Sun and F. Robicheaux, Phys. Rev. A 78, 040701 (2008)
[3] H. Schempp *et al.*, Phys. Rev. Lett. 104, 173602 (2010)

Q 57.65 Thu 16:30 P1

Mean-field models for correlated Rydberg gases — •Kilian Heeg and Jörg Evers — Max-Planck-Institut für Kernphysik, Heidelberg, Germany

Mean field models are discussed for the description of clouds of Rydberg atoms. We are in particular interested in situations in which n-body correlations with n>2 are of importance, such as in recent experiments on coherent population trapping in Rydberg atoms. We compare different approaches with each other, with experimental data, and with more demanding numerical models, with the aim of estimating the validity range.

Q 57.66 Thu 16:30 P1

Towards experiments with ultracold Rydberg gases at high atomic densities — •Aline Faber, Hannes Busche, Christoph Hofmann, Georg Günter, Hanna Schempp, Martin de Saint-Vincent, Shannon Whitlock und Matthias Weidemüller — Physikalisches Institut, Universität Heidelberg, Philosophenweg 12, 69120 Heidelberg

Rydberg atoms have gained much interest in recent years due to the remarkable fact that their properties like the dipole-dipole interaction or the lifetime can readily be tuned over several orders of magnitude [1]. Latest developments are aiming for effects occurring in ultracold and very dense atomic samples, like Ryberg-ground state molecule formation [2] or dynamical crystallization [3].

We report on the status of our new Rydberg apparatus. The setup combines large optical access with a high level of electric field control. A compact 2D-MOT serves as a high flux source of cold atoms. Combined with all-optical Bose-Einstein condensation in an optical trap at 1064nm the new apparatus will allow for duty cycles of several seconds. The large optical access makes the setup versatile and will allow us to perform Rydberg excitation in very dense atomic samples as well as in optical lattices.

[1] Saffman et al., Rev.Mod.Phys. 82, 2313 (2010)
[2] Bendkowsky et al., Nature 458, 1005 (2009)
[3] Pohl et al., Phys.Rev.Lett. 104, 043002 (2010)

Q 57.67 Thu 16:30 P1

An electron microscope for the detection and manipulation of Rydberg atoms — •Tobias Weber, Torsten Manthey, Julia Grün, Thomas Niederprüm, Vera Guarrera, Giovanni Barontini, and Herwig Ott — Fachbereich Physik, Universität Kaiserslautern

The strong dipole-dipole interaction between Rydberg atoms leads to a huge number of exotic and interesting phenomena (e.g. plasma formation or dipole blockade) that can be studied in the realm of ultracold quantum gases, especially when optical lattices are present. In this poster, we will present a new apparatus for the production, the manipulation and the detection of ultracold Rydberg atoms in optical lattices. The main feature of this apparatus is the presence of a scanning electron microscope inside the vacuum chamber that will allow us the manipulation and the detection of single Rydberg atoms in each lattice site.

Q 57.68 Thu 16:30 P1

A new cavity QED apparatus at work — •Haytham Chibani, Markus Koch, Christian Sames, Maximilian Balbach, Alexander Kubanek, Alexei Ourjoumstev, Pepijn Pinkse, Karim Murr, Tatjana Wilk, and Gerhard Rempe — Max Planck-Institut für Quantenoptik, Hans-Kopfermann-Str. 1, 85748 Garching, Germany

Manipulating the dynamical processes of individual quantum systems quantum by quantum, is one of the most important goals in modern physics. Our quantum system consists of a single atom strongly coupled to a single mode of an optical resonator. We developed a new setup [1] which features an asymmetric cavity with one of the mirrors having a higher transmission. The resulting higher information rate allows an efficient implementation of a real-time feedback scheme which cools the motion of a single atom trapped inside the resonator and, hence, also increases its storage time. The longer storage time in conjunction with the enhanced transmission increases the effective duty cycle of the experiment by almost 3 orders of magnitude compared to our previous work [2]. This paves the way to measure higher order intensity correlations of the transmitted probe light. As a first step towards this goal, we measured the time-dependent three-photon correlation function of the probe light while single atoms were passing through the cavity mode. These measurements provide unique information on the system dynamics, in particular on the doubly excited dressed states.

[1] M. Koch et al., Phys. Rev. Lett. 105, 173003 (2010)
[2] A. Kubanek et al., Nature 462, 898-901 (2009)

Q 57.69 Thu 16:30 P1

Fallendesignstudien für eine deterministische hochauflösende Einzelionenquelle — •Georg Jacob, Stefan Ulm, Andreas Kehlberger, Stefan Weidlich, Ferdinand Schmidt-Kaler und Kilian Singer — Johannes Gutenberg-Universität, Institut für Physik, 55128 Mainz, Deutschland

In den von uns bisher durchgeführten Experimenten wurde eine deterministische Einzelionenquelle auf Basis einer segmentierten Paulfalle realisiert [1]. Auch wurde bereits die Fokusierbarkeit eines mit diesem System erzeugten Ionenstrahls gezeigt [2]. Um die theoretischen Vorhersagen bezüglich der räumlichen Auflösung zu bestätigen ist es unerlässlich die Ionen vor dem Extrahieren in den Grundzustand der Bewegung zu kühlen [3]. Da dies hohe Fallenfrequenzen erfordert und es gleichzeitig notwendig ist die Ionenkristalle in der Falle zu trennen und zu transportieren [4], wurde ein mikrostrukturierter Aufbau gewählt. Des Weiteren wurde die Fallengeometrie mittels numerischer Verfahren [5] hinsichtlich den Anforderungen an die Emittanz und der Geschwindigkeitsverteilung des Ionenstrahls optimiert.

[1] W. Schnitzler et al., Phys. Rev. Lett. **102**, 070501 (2009)
[2] W. Schnitzler et al., NJP **12**, 065023 (2010)
[3] R. Fickler et al., J. Mod. Optics **56**, 2061 (2009)
[4] J. Eble et al., JOSA B **27**, A99 (2010)
[5] K.Singer et al., RMP **82**, 2609 (2010)

Q 57.70 Thu 16:30 P1

Laser cooling of dense atomic gases by collisional redistribution of radiation — •Simon Hasselmann, Anne Sass, Ulrich Vogl, and Martin Weitz — Institut für Angewandte Physik der Universität Bonn, Wegelerstr. 8, 53115 Bonn

We report on a laser cooling mechanism based on collisional redistribution of fluorescence in high pressure gas mixtures of alkali- and noble gas atoms. During atomic collisions in such a strongly pressure broadened system, far red detuned radiation can be absorbed and afterwards be reemitted closer to the unperturbed resonance. During each excitation cycle, kinetic energy of the order of the thermal energy kT is extracted from the sample. In our experiments we use alkali atoms in argon buffer gas at a pressure of several hundred bar and we observe temperature changes up to 527 K within a tenth of a second from an initial temperature of 680 K. The cooling power of this method is four to five orders of magnitude larger than in the Doppler cooling of dilute atomic gases.

Further prospects of the method include the rapid laser cooling of dense gases beyond the critical point of the gas, where investigations of supercooled fluids become viable. We are also planning to explore the cooling of molecular gases with redistribution laser cooling.

Q 57.71 Thu 16:30 P1

Inelastic scattering of a probe particle on a Bose-Einstein condensate — •Stefan Hunn[1], Moritz Hiller[1], Tsampikos Kottos[2], Doron Cohen[3], and Andreas Buchleitner[1] — [1]Albert-Ludwigs-Universität Freiburg, Hermann-Herder-Str. 3, 79104 Freiburg — [2]Department of Physics, Wesleyan University, CT, USA — [3]Department of Physics, Ben-Gurion University, Beer-Sheva, Israel

We devise a microscopic scattering approach to probe the excitation spectrum of a Bose-Einstein condensate: A probe particle with momentum k moves in a waveguide which is placed in the proximity of a BEC confined by an optical lattice. When the particle approaches the condensate, it exchanges energy with the latter. We investigate the statistical properties of the resulting inelastic scattering process. In the parameter regime where the inter-atomic interactions induce chaotic spectral statistics, the inelastic cross section exhibits universal Ericson fluctuations. On the other hand, we show how a mixed regular/chaotic phase space of the underlying mean-field dynamics is reflected in the sparsity of the scattering matrix.

Q 57.72 Thu 16:30 P1

Optical vortices of slow light using tripod scheme — •Algirdas Mekys, Julius Ruseckas, and Gediminas Juzeliunas — Institute of Theoretical Physics and Astronomy, Vilnius University, A. Goštauto 12, LT-01108 Vilnius, Lithuania

We consider propagation, storing and retrieval of slow light in a resonant atomic medium of cold atoms illuminated by two control laser beams of larger intensity [1,2]. The probe and two control beams act on atoms in a tripod configuration of the light-matter coupling. The first control beam is allowed to have an orbital angular momentum. Application of the second vortex-free control laser ensures the lossless (adiabatic) propagation of the probe beam at the vortex core where the intensity of the first control laser goes to zero. Storing and release of the probe beam is accomplished by switching off and on the control laser beams leading to the transfer of the optical vortex from the first control beam to the regenerated probe field. A part of the stored probe beam remains frozen in the medium in the form of atomic spin excitations, a number of which increases with increasing the intensity of the second control laser. We analyze such losses in the regenerated probe beam and provide conditions for the optical vortex of the control beam to be transferred efficiently to the restored probe beam.

[1] A. Raczynski, J. Zaremba, and S. Zielinska-Kaniasty, Phys. Rev. A, **75**, 013810 (2007).

[2] J. Ruseckas, A. Mekys, and G. Juzeliunas, Opt. Spektrosc. **108**, 438 (2010).

Q 57.73 Thu 16:30 P1

Towards a two-species mixed gas of ^{6}Li and ^{133}Cs atoms and LiCs molecules at high phase-space densities — •Stefan Schmidt[1], Marc Repp[1], Johannes Deiglmayr[2], Rico Pires[1], Juris Ulmanis[1], Romain Müller[1], Kristina Meyer[1], Roland Wester[3], and Matthias Weidemüller[1] — [1]Physikalisches Institut, Ruprecht-Karls-Universität Heidelberg — [2]Physikalisches Institut, Albert-Ludwigs-Universität Freiburg — [3]Institut für Ionenphysik und Angewandte Physik, Leopold-Franzens-Universität Innsbruck

The LiCs dimer is a particularly promising candidate for observing dipolar effects, as it possesses the largest dipole moment of 5.5 Debye of all alkali dimers [1]. We have studied the formation of LiCs molecules via photoassociation [2] at MOT temperatures. The population dynamics of ro-vibrational states in a trapped sample of ultracold LiCs molecules via black-body driven transitions or spontaneous decay was further investigated [3].

This poster will present the current status of a redesign of our experimental apparatus. A double-species Zeeman slower will allow to consecutive decelerate Cs and Li atoms. Further cooling steps, like Raman sideband cooling of Cs atoms and forced evaporative cooling in independent dipole traps, will bring the species to quantum degeneracy. After bringing the two gases together, molecules are to be formed via Feshbach resonances followed by a STIRAP step.

[1] J. Deiglmayr *et al.*, Phys. Rev. A 82, 032503 (2010)

[2] J. Deiglmayr *et al.*, Phys. Rev. Lett. 101, 133004 (2008)

[3] J. Deiglmayr *et al.*, in preparation

Q 57.74 Thu 16:30 P1

Spectroscopic determination of YbRb ground state potentials — Frank Münchow, •Cristian Bruni, Maximilian Madalinski, and Axel Görlitz — Institut für Experimentalphysik, HHU Düsseldorf, 40225 Düsseldorf

Ultracold heteronuclear molecules offer fascinating perspectives ranging from ultracold chemistry to novel interactions in quantum gases. In our experiment, the ultimate goal is the production of ultracold YbRb molecules in the electronic and rovibrational ground state. The special property of these molecules is that they possess a magnetic as well as an electric dipole moment. As a first step, we have already observed the production of weakly bound and vibrationally highly excited molecules via photoassociation in a combined magneto-optical trap close to the Rb D1-line at 795 nm [1].The next step which is currently under investigation is the spectroscopic determination of the vibrational structure of the electronic ground state. This will be done by so-called Autler-Townes spectroscopy where a second laser is used to probe transitions between the ground and excited molecular state. The knowledge of the molecular binding energies and thus the potential curves will be crucial on the way to the formation of ground state molecules either by STIRAP or using Feshbach resonances.

[1] N. Nemitz, F. Baumer, F. Münchow and A. Görlitz, Phys. Rev. A 79, 061403(R) (2009)

Q 57.75 Thu 16:30 P1

Two dimensional arrays of ultra cold polar molecules: possible structural transitions — •Sofia Kantorovich[1,2], Rudolf Weeber[2], Christian Holm[2], and Hans Peter Buechler[3] — [1]Ural State University, Lenin av. 51, Ekaterinburg, 620000, Russia — [2]ICP, Universitaet Stuttgart, Pfaffenwaldring 27, 70569, Stuttgart, Deutschland — [3]ITP III, Universitaet Stuttgart, Pfaffenwaldring 57, 70550, Stuttgart, Deutschland

Polar molecules have attracted a lot of interest due to their large electric dipole moment, which in combination with external electric fields gives rise to strong dipole-dipole interactions. Recent experimental advances allowed to confine polar molecules by an optical lattice along one axes so, that a set of parallel layers is built. Each dipole moment points along the same axis, therefore, the structure within the layer is dominated by the repulsion, and the interaction between layers is mainly attractive. Here we focus on the classical regime, where the dipole-dipole interaction dominates over the kinetic contribution, and study the ground state of the array of strings of ultra cold polar molecules as a function of the ratio between intermolecular distance within one string and the separation of the strings, and showed that at a certain range one observes a structural transition from the simple square lattice to a 2D hexagonal one. Hence, by changing this ratio one can control ground state configurations, opening new possibilities for an experimental control of the ultra cold polar molecules' arrays. Quantum fluctuations can be implemented in this approach via perturbation theory.

Q 57.76 Thu 16:30 P1

Berry phase in atom optics — •Polina V. Mironova[1,2], Maxim A. Efremov[3], and Wolfgang P. Schleich[1] — [1]Institut für Quantenphysik, Universität Ulm, D-89069 Ulm — [2]Institut für Angewandte Physik, Technische Universität Darmstadt, D-64289 Darmstadt — [3]LPTMS, Université Paris-Sud, 15 rue Georges Clémenceau, F-91405 Orsay cedex

We consider the scattering of a two-level atom from a near-resonant standing light wave. Within the Raman-Nath approximation on the atomic center-of-mass motion, adiabatic turn-on and -off of the interaction together with the rotating wave approximation we obtain a condition for the cancelation of the dynamical phase and show that the scattering picture is determined only by the Berry phase dependent on the internal and external atomic degrees of freedom. Moreover, we propose a novel possibility to observe the Berry phase based on the atomic lens construction. This application of the Berry phase might be useful in the lithography with cold atoms.

We enlarge our analysis of the Berry phase in atom optics by considering the case of atomic scattering by the traveling wave, where we take the kinetic energy operator into account. Here we present the exact solution in the case of the inverse-cosh envelope of the electromagnetic field, and show that it is the same as the result derived within the Berry's approach.

Q 57.77 Thu 16:30 P1

Towards a miniaturized frequency comb system for atom optics in microgravity — •Hannes Duncker[1], André Wenzlawski[1], A. Jones Rafipoor[1], Patrick Windpassinger[1], Klaus Sengstock[1], and the Lasus Team[1,2,3,4] — [1]Institut für Laser-Physik, Universität Hamburg, Luruper Chaussee 149, 22761 Hamburg — [2]Institut für Quantenoptik, Leibniz Universität Hannover, Welfengarten 1, 30167 Hannover — [3]Institut für Physik, Humboldt Universität zu Berlin, Newtonstr. 15, 12489 Berlin — [4]Ferdinand-Braun-Institut, Leibniz-Institut für Höchstfrequenztechnik, Gustav-Kirchhoff-Str. 4, 12489 Berlin

Atom optics under microgravity places stringent requirements on the deployed laser systems in terms of reliability, robustness, weight, volume and power consumption. Within this project, new technologies are developed which meet these demands to support experiments performed within the QUANTUS project at the drop tower in Bremen and make future sounding rocket missions feasible. For the latter, a compact glassceramic based splitting module is developed to allow for reliable switching and modulation of laser light for the generation and manipulation of ultracold Rubidium. Furthermore, a frequency comb system in a form factor suitable for microgravity platforms is currently in its design phase. Such a system paves the way for tests of the universality of free fall using a dual species atom interferometer.

The project is supported by the German Space Agency DLR with funds provided by the Federal Ministry of Economics and Technology (BMWi)under grant number DLR 50WM 0938.

Q 57.78 Thu 16:30 P1

Advanced laser system for atom interferometry — •Christoph Grzeschik[1], Max Schiemangk[1], Achim Peters[1], and the QUANTUS Team[1,2,3,4,5,6,7,8,9] — [1]Institut für Physik, HU Berlin — [2]Institut für Quantenoptik, LU Hannover — [3]Institut für Laserphysik, Uni Hamburg — [4]ZARM, Uni Bremen — [5]Institut für Quantenphysik, Uni Ulm — [6]MPQ, München — [7]Institut für angewandte Physik, TU Darmstadt — [8]Midlands Ultracold Atom Research Centre, University of Birmingham, UK — [9]FBH, Berlin

In preparation for future quantum gas experiments in space, preliminary experiments are currently performed at the ZARM drop tower in Bremen and a sounding rocket mission is planned for the near future.

The poster presents key components of a compact and robust laser systems, e.g. a Raman laser system and a hybrid integrated master oscillator power amplifier (MOPA). To provide an intrinsic phase stability the Raman laser system is based on injection locking of modulated light. Capture range measurements and the suppression of parasitric frequencies have been investigated with different types of injected diodes. The MOPA, whose components are integrated on a 10×50 mm^2 microbench, allows for outputpower in the Watt range, while preserving the spectral characterisics of the DFB laser diode, which has an intrinsic linewidth of approx. 100 kHz at operation conditions.

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 DLR 50WM1131-1137.

Q 57.79 Thu 16:30 P1

Interferometry with Bose-Einstein condensates in microgravity — •Holger Ahlers[1], Naceur Gaaloul[1], Stephan Seidel[1], Waldemar Herr[1], Jan Rudolph[1], Christina Rode[1], Dennis Becker[1], Manuel Popp[1], Thijs Wendrich[1], Wolfgang Ertmer[1], Ernst Maria Rasel[1], and the QUANTUS Team[2,3,4,5,6,7,8,9] — [1]Institut für Quantenoptik, LU Hannover — [2]Institut für Quantenphysik, Universität Ulm — [3]ZARM, Universität Bremen — [4]Institut für Physik, HU Berlin — [5]Institut für Laser-Physik, Universität Hamburg — [6]Institut für angewandte Physik, TU Darmstadt — [7]Midlands Ultracold Atom Research Centre, University of Birmingham, UK — [8]FBH, Berlin — [9]MPQ, Garching

Matter-wave sensors are considered as one of the most promising fields to progress in metrology and fundamental tests. In this poster, we report about the development of a miniaturized and robust experiment using ultra cold atoms in a free fall environment as a test-bed for matter-wave interferometry on long timescales. More than 200 experiments were successfully performed in microgravity and a BEC was observed after free expansions of up to 1s [1]. The implementation of an atom interferometer operating with a Bose-Einstein Condensate was recently demonstrated and several experiments carried out.

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 DLR 50 WM 1131.

[1] T. van Zoest et al., Science **328**, 1540 (2010).

Q 57.80 Thu 16:30 P1

A dual species matter-wave interferometer in microgravity — •Dennis Becker[1], Waldemar Herr[1], Jan Rudolph[1], Manuel Popp[1], Christina Rode[1], Thijs Wendrich[1], Holger Ahlers[1], Stephan Seidel[1], Naceur Gaaloul[1], Wolfgang Ertmer[1], Ernst Maria Rasel[1], and the QUANTUS Team[2,3,4,5,6,7,8,9] — [1]Institut für Quantenoptik, LU Hannover — [2]ZARM, Universität Bremen — [3]Institut für Physik, HU Berlin — [4]Institut für Laser-Physik, Universität Hamburg — [5]Institut für Quantenphysik, Universität Ulm — [6]Institut für angewandte Physik, TU Darmstadt — [7]MUARC, University of Birmingham, UK — [8]FBH, Berlin — [9]MPQ, Garching

The aim of QUANTUS-II is to test the weak equivalence principle in the quantum domain using matter-wave interferometry. To this end, a degenerated Bose-Fermi mixture of ^{87}Rb and ^{40}K will be created in microgravity to take advantage of an extended time of free evolution. Our compact atom chip based setup can employ the catapult mode of the drop tower in Bremen, which provides up to 9 seconds of microgravity. The poster shows the setup, the up to date progress and future prospects of this ambitious and technically challenging project. 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 DLR 50 WM 1131.

Q 57.81 Thu 16:30 P1

Compact electronics for laser system in microgravity — •Thijs Wendrich, Wolfgang Ertmer, and Ernst Maria Rasel — Leibniz Universität Hannover, Institut für Quantenoptik

Microgravity experiments with ultra cold degenerate quantum gases require very compact and robust apparatuses that contain everything for the experiment like vacuum, lasers, optics, and the electronics. The LASUS project develops diode lasers, optical modules and electronics for such experiments, and specifically for the QUANTUS microgravity experiments. The focus of this contribution is on how to make all of the electronics to control the entire laser system for capturing and manipulating rubidium and potassium together with the electronics for the optical switching and frequency shifting, fit in a volume of a few liters. This will be achieved by a computer controlled modular setup using custom build high density circuit boards with mainly SMD components and by having all settings remote controlled via the onboard computer. Another key component in the miniaturization is the FPGA-based frequency controller which integrates several conventional PID controllers and modulation and demodulation devices for several laser systems in a single compact device. The LASUS project is a collaboration of FBH Berlin, HU Berlin, U Hamburg and LU Hannover supported by the German Space Agency DLR with funds provided by the Federal Ministry of Economics and Technology (BMWi) under grant number 50WM0939.

Q 57.82 Thu 16:30 P1

Active low frequency vibration isolation for high precision atom interferometry — •Christian Freier — Humboldt Universität Berlin

The performance of high precision atom interferometers is often limited by vibrations of optical components introducing Raman phase noise. We have built and characterized an active low frequency vibration isolation platform which isolates one key component of our atom interferometer from environmental vibrations and allows us to perform high precision gravity measurements.

The platform combines a 0.5 Hz commercial spring-based passive vibration isolator with a custom built feedback loop. The active feedback system measures residual vibrations on the platform using a commercial weak-motion seismometer. This acceleration signal is fed back into voice coil actuators which exert a force on the floating isolator in order to cancel out the residual vibrations.

Using this method the resonance frequency of the isolator has been lowered to 0.03 Hz, which enables high performance low-frequency vibration isolation in a small portable package.

Q 57.83 Thu 16:30 P1

Length sensing and control of the AEI 10 m Prototype sub-SQL interferometer — •Christian Gräf for the AEI 10m Prototype Team — Max-Planck-Institut für Gravitationphysik (Albert-Einstein- Institut), Institut für Gravitationsphysik, Leibniz Universität Hannover und QUEST

The AEI 10 m Prototype sub-SQL interferometer, which is currently being set up at the AEI in Hannover, Germany, aims at beating the Standard Quantum Limit (SQL) at Fourier frequencies of ~ 100 Hz, reaching for a displacement sensitivity of $\sim 10^{-19}\,\mathrm{m}/\sqrt{\mathrm{Hz}}$. Reducing the impact of fluctuations on the lengths in the optical setup is crucial for the instrument to unfold its full potential for ultra-high sensitiv-

ity measurements of the differential mode of its interferometer arms. Electronic feedback control has proven an essential tool to fulfill this requirement by actively feeding back length error signals, obtained by phase modulation/demodulation techniques, to the suspended optics of the interferometer. A high-performance real time digital control system is employed to hold the multitude of length degrees-of-freedom tightly at predefined operating points. Due to the high complexity of the underlying optical system, simulations play a key role in the design of the signal extraction and control scheme.
In this talk an overview of selected aspects of the longitudinal sensing and control system design for the AEI 10 m Prototype sub-SQL interferometer is given.

Q 57.84 Thu 16:30 P1

Optische Tests an einem Dreifachspiegel für eine schnelle GRACE (Gravity Recovery and Climate Experiment) Nachfolgemission — •Gunnar Stede, Benjamin Sheard, Gerhard Heinzel und Karsten Danzmann — Albert-Einstein-Institut Hannover, Max-Planck-Institut für Gravitationspyhsik und Institut für Gravitationsphysik der Universität Hannover

GRACE ist eine Satellitenmission zur Vermessung des Erdschwerefeldes, basierend auf Abstandsmessungen, zweier 200km zueinander entfernten Satelliten, im Submikrometerbereich. In einer schnellen GRACE Nachfolgemission kann das vorhandene Mikrowelleninterferometer durch ein Laserinterferometer ergänzt werden um die Auflösung zu erhöhen. Da die optische Achse zwischen den beiden Masseschwerpunkten durch das Mikrowelleninterferometer versperrt ist, muss der Laserstrahl um dieses herum geführt werden. Damit die gemessene optische Weglänge auch im Falle einer Fehlausrichtung der Satelliten konstant bleibt, wird ein sogenannter Dreifachspiegel benutzt, dessen optische Weglänge unabhängig von seiner Orientierung ist. Hier stellen wir Testmethoden des Dreifachspiegels und erste Ergebnisse vor.

Q 57.85 Thu 16:30 P1

Optical simulations for inter-satellite interferometry — •Christoph Mahrdt, Evgenia Granova, Benjamin Sheard, Gudrun Wanner, Gerhard Heinzel, and Karsten Danzmann — Max-Planck-Institut für Gravitations Physik (Albert-Einstein-Insitut) , Hannover und QUEST, Leibniz Universität Hannover

High precision metrology based on laser interferometry between satellites is currently under development for fundamental physics missions such as LISA or earth observation missions like a GRACE follow-on. These missions will measure the relative distance between two satellites with an unprecedented accuracy. The development of optical systems for these missions is highly demanding, since issues such as stray light, wavefront errors, beam pointing and optical pathlength stability have to be taken care of. Careful analysis of the optical setups need to be done and not all properties of an inter-satellite interferometer can be tested on ground. Therefore, optical simulations are needed to find possible error sources, optimise the setups and to find requirements on the placement and alignment of optical components. A software toolkit currently under development combines raytracing with Gaussian beam propagation for calculation of optical pathlength, the beam axes and interferometer signals, including phase and differential wavefront sensing. To trace non-Gaussian beams through interferometers, decomposition into Hermite-Gauss modes is implemented and under verification. Another part under development is the implementation of general astigmatism for Gaussian beams. This talk will give an overview of the simulation software, its status and applications.

Q 57.86 Thu 16:30 P1

Pre-experiments for the LISA optical bench — •Christian Diekmann, Johanna Bogenstahl, Marina Dehne, Roland Fleddermann, Evgenia Granova, Gudrun Wanner, Michael Troebs, Gerhard Heinzel, and Karsten Danzmann — Max-Planck Institute for Gravitational Physics (Albert Einstein Institut), Hannover and QUEST, Leibniz University Hannover

The space-based gravitational wave detector Laser Interferometer Space Antenna (LISA) will detect gravitational waves in the frequency range between 0.03 mHz and 1 Hz. This will be done by measuring distance changes between free-flying testmasses. The key elements for these measurements are the so-called optical benches. A prototype of these benches is currently being built for the European Space Agency (ESA). For this purpose, several pre-experiments like the backlink fiber experiment had to be performed. This and other experiments will be discussed in the presentation.

Q 57.87 Thu 16:30 P1

The LISA optical bench — •Johanna Bogenstahl, Gerhard Heinzel, Michael Troebs, Christian Diekmann, Roland Fleddermann, Gudrun Wanner, Evgenia Granova, Marina Dehne, and Karsten Danzmann — Max Planck Institute for Gravitational Physics (Albert Einstein Institute) Callinstr. 38 D-30167 Hannover

The space-based gravitational wave detector Laser Interferometer Space Antenna (LISA) shall detect gravitational waves by measuring distance changes between its three satellites using interferometers. Currently, the first prototype of the so-called optical bench, that contains the interferometric setups for the lengths measurements of LISA, is being built for the European Space Agency (ESA). This optical bench will be tested at the Albert Einstein Institute and its functionality and sensitivity will be characterised. For this purpose, special tools and pre-experiments are necessary that will be discussed in the presentation.

Q 57.88 Thu 16:30 P1

Avoiding blackbody radiation shifts, density shifts, and fiber-induced laser degradation in an optical lattice clock — •Thomas Middelmann, Stephan Falke, Stefan Vogt, Fritz Riehle, Uwe Sterr, and Christian Lisdat — Physikalisch-Technische Bundesanstalt, Bundesallee 100, 38116 Braunschweig

With our recent frequency measurement of the $^1S_0 - {}^3P_0$ transition of ^{87}Sr we reached a level of precision that opens the demand for investigations of the blackbody radiation shift. The blackbody radiation of the ambient housing at 300 K causes a shift of 5×10^{-15} and the correction leaves an uncertainty of 1.6×10^{-16} due to uncertainty of the temperature sensitivity coefficient and incomplete characterization of the environmental temperature. We will present the status of our experiments aiming at measuring the coefficient and to work at 77 K.

In current optical lattice clock experiments inhomogeneous excitation makes fermions distinguishable and thus collision shifts are observed. An imperfect alignment or wave front distortion of the clock laser beam causes motional state-dependent Rabi frequencies leading to motional state-dependent superposition states. The atoms lose their initial indistinguishability and are subject to s-wave collisions. By controlling the inhomogeneity of the excitation we investigate this effect.

Moreover, a fiber length stabilization was applied for the spectroscopy pulse to ensure that no significant frequency chirps occur during the 90 ms spectroscopy pulse. The work is supported by the Centre for Quantum Engineering and Space-Time Research (QUEST), ESA, DLR, and the ERA-NET Plus Programme.

Q 57.89 Thu 16:30 P1

Quantenrausch-limitierte Laser-Amplitudendetektion von Hochleistungslasern — •Patrick Kwee, Benno Willke und Karsten Danzmann — Albert-Einstein-Institut Hannover

Viele Präzisionsmessungen verwenden Modulationstechniken bei Radiofrequenzen ab 10 MHz, um störende Rauschquellen bei niedrigen Frequenzen zu vermeiden. Diese Techniken setzen allerdings eine empfindliche Detektion der Laser-Amplitude in diesem Frequenzbereich voraus. Das fundamentale Limit ist das Quantenrauschen, das von der detektierten Laserleistung abhängt, wobei eine höhere Leistung die Empfindlichkeit verbessert.

Die heute verwendeten Photodioden sind hier üblicherweise bei einer Leistung von ca. 10. . . 100 mW durch die Zerstörschwelle der Photodiode und durch den dynamischen Bereich der Ausleseelektronik limitiert. Dies steht im Kontrast zu den verfügbaren Laserleistungen von bis zu ca. 100 W im Bereich der Präzisionsmessungen.

Ein Experiment wird vorgestellt, dass die *Optical AC Coupling* Technik verwendet, um eine quantenrausch-limitierte Amplitudendetektion von 10. . . 100 W Laserstrahlen zu erlauben. Dabei wird ein optischer Resonator verwendet, um die Empfindlichkeit einer Photodiode zu erhöhen. Eine etwa tausendfach höhere Leistung im Gegensatz zu einer einfach Photodiode kann detektiert werden. Erste Messungen an einem 1064 nm Nd:YAG Laser bei Frequenzen zwischen 10. . . 100 MHz werden vorgestellt.

Q 57.90 Thu 16:30 P1

Towards a Portable Aluminum Optical Clock — •Jannes B. Wübbena, Sana Amairi, Olaf Mandel, Ivan V. Sherstov, and Piet O. Schmidt — QUEST Inst. for Exp. Quantum Metrology, PTB Braunschweig and Leibniz Univ. of Hannover, Germany

Optical Aluminum ion clocks were the first and until now the only clocks to achieve a fractional frequency inaccuracy lower than 1×10^{-17}

[1]. This accuracy enables many applications, varying from frequency metrology to relativistic geodesy. Here we report on the status of a movable Aluminum ion clock that will allow transport to other sites for high accuracy frequency comparisons.

The 267 nm $^1S_0 \leftrightarrow {}^3P_0$ transition in $^{27}Al^+$ is a superior candidate for frequency standards because it has a very narrow line width (8 mHz), no electric quadrupole shift and the lowest known blackbody radiation shift among all atomic species currently considered for clocks. Limitations arising from the lack of an accessible cooling and state detection transition in Aluminum will be overcome by trapping the $^{27}Al^+$ together with a $^{40}Ca^+$ ion. This "logic ion" is Doppler cooled and will sympathetically cool the Aluminum. Techniques developed for quantum information processing will be used to transfer the atomic state of the Al^+ to the Ca^+ where high efficiency electron-shelving detection is available.

[1] C.W. Chou *et al.*, Phys. Rev. Lett. 104, 070802 (2010)

Q 57.91 Thu 16:30 P1

A Single Laser System for Ground State Cooling of $^{25}Mg^+$ — •Florian Gebert, Börge Hemmerling, Yong Wan, Ivan V. Sherstov, and Piet O. Schmidt — QUEST Inst. for Exp. Quantum Metrology, PTB Braunschweig and Leibniz Univ. of Hannover, Germany

We present a single solid-state laser system to cool, coherently manipulate and detect $^{25}Mg^+$ ions confined in a linear Paul trap. Coherent manipulation is accomplished by coupling two hyperfine ground state levels using a pair of far-detuned Raman laser beams. Resonant light for Doppler cooling and detection is derived from the same laser source using the sidebands of an electro-optic modulator. With this setup we cooled the axial vibrational mode of a single $^{25}Mg^+$ ion to the ground state using resolved sideband cooling. Its performance is studied by the time evolution of the Raman-stimulated sideband transitions. Our Setup is a major simplification over existing state-of-the-art systems, typically involving up to three separate laser sources. With this setup we will perform direct frequency comb spectroscopy using quantum logic to determine important transitions of Ca^+, Ti^+ and Fe^+ for the comparison with quasar absorption spectra to study possible time variation of the fine structure constant α. In our experiment the quantum logic scheme [2] will be used for cooling and state detection. Another application of our setup will be the cooling of molecular ions to their internal ground state.

[1] B. Hemmerling *et al.*, arXiv:1010.5664v1 [quant-ph]
[2] P. O. Schmidt *et al.*, Science 309, 749-752 (2005)

Q 57.92 Thu 16:30 P1

Strontium in an Optical Lattice as a Mobile Frequency Reference — •Ole Kock, Steven Johnson, Yeshpal Singh, and Kai Bongs — School of Physics and Astronomy, University of Birmingham, United Kingdom

The higher frequencies (10^{15} Hz) of the atomic transitions enable a greater accuracy than the current microwave frequency (10^{10} Hz) standard. Optical clocks have now achieved a performance significantly beyond that of the best microwave clocks, at a fractional frequency uncertainty of $8.6 * 10^{-18}$ [Chou]. With the rapidly improving performance of optical clocks, in the future, most applications requiring the highest accuracy will require optical clocks. We are setting up an experiment aimed at a mobile frequency standard based on strontium (Sr) in a blue detuned optical lattice. Sr is an alkaline-earth element and has two electrons in its outer shell, which give rise to a singlet state (ground state) and a triplet state. The dipole transitions from a singlet state to a triplet state are forbidden, which results in a long meta-stable lifetimes and as narrow line widths as one mHz. The unprecedented accuracy in time promises new applications like relativistic geodesy for exploration of oil and minerals, fundamental tests of general relativity and synchronization for long base line astronomical interferometry. It is worth mentioning that very recently, space has also opened up as a new venue for precision measurements based on cold atoms. An up to date progress on a compact and robust frequency standard experiment will be presented. 1) C.W. Chou, D. B. Hume, J. C. J. Koelemeij, D. J. Wineland, and T. Rosenband, PRL 104, 070802 (2010).

Q 57.93 Thu 16:30 P1

High performance iodine frequency reference aiming at a stability of 1×10^{-15} — •Klaus Döringshoff, Katharina Möhle, Moritz Nagel, Evgeny V. Kofvalchuk, and Achim Peters — Humboldt-Universität zu Berlin, Institut für Physik, AG Optische Metrologie, Newtonstr. 15, 12489 Berlin

Future space missions, including the Laser Interferometer Space Antenna (LISA), rely on laser systems with high frequency stability over long time scales. Hyperfine-resolved optical transitions in molecular iodine (I_2) could provide stable references for space missions, but also for terrestrial applications. The narrow linwidth of the hyperfine components (≈ 300 kHz) at 532 nm and strong absorption coefficient in combination with intrinsically stable frequency doubled Nd:YAG lasers allow for the realization of highly frequency stable, reliable and practical secondary frequency standards. Here we present our iodine frequency reference for the validation of tunable optical frequency references for the spaceborne gravitational wave detector LISA. For absolute frequency stabilization the frequency doubled output of a 1064 nm Nd:YAG laser is stabilized to the a_{10} component of the R(56)32-0 transition of $^{127}I_2$. Using a 80 cm iodine cell and the MTS technique a frequency stability of 1×10^{-14} at 1 s and 5×10^{-15} at 100 s integration time is achieved. We present our efforts aiming at a frequency stability of 1×10^{-15} at averaging times of 1000 s.

This work is supported the German Space Agency DLR with funds provided by the Federal Ministry of Economics and Technology (BMWi) under grant number DLR 50OQ0601.

Q 57.94 Thu 16:30 P1

A mobile atom interferometer for high precision measurement of local gravity — •Vladimir Schkolnik, Malte Schmidt, Alexander Senger, Matthias Hauth, Christian Freier, and Achim Peters — Institut für Physik, HU Berlin, Germany

GAIN (Gravimetric Atom Interferometer) is a mobile gravimeter, which is based on interfering ensembles of laser cooled ^{87}Rb atoms in an atomic fountain configuration. With a targeted accuracy of a few parts in 10^{10} for the measurement of local gravity, g, this instrument will offer about an order of magnitude improvement in performance over the best currently available absolute gravimeters.

This poster will outline the working principle of our mobile gravimeter and describe its subsystems in detail. Furthermore we present first measurements after the move into our new building and discuss plans for future improvements.

Q 57.95 Thu 16:30 P1

Paving the way to coherent modern control of quantum optical systems — Timo Denker, Dirk Schütte, Maximilian Wimmer, and •Michèle Heurs — Albert-Einstein-Institut Hannover, Max-Planck-Institut für Gravitationsphysik und Centre for Quantum Engineering and Space-Time Research (QUEST), Leibniz Universität Hannover, Welfengarten 1, 30167 Hannover, Germany

Modern control techniques offer highly attractive possibilities when applied to stabilisation tasks in quantum optics and interferometric gravitational wave detection. The approach is inherently multivariable and incorporates a concept of optimality. Moreover, the feasibility of the stabilisation task is known a priori. The highly systematic approach to control yields a thorough understanding of the underlying physics of the system under consideration.

Coherent control on the other hand is a technique of stabilisation that doesn't measure the variable of interest, thereby offering tantalising possibilities for QND type schemes. Recent implementations include the work by Mabuchi et al..

We present our roadmap to achieve a merging of modern and coherent control in the future, and propose experiments to finally reach this goal. We will show recent, current and future quantum optical applications for modern control techniques and coherent control. As an example of modern control in quantum optics we present the frequency stabilisation of an optical cavity, to exemplify the latter we will show preliminary work of treating recycling techniques in interferometric gravitational wave detectors as a coherent control problem.

Q 57.96 Thu 16:30 P1

Stabilization of the Advanced LIGO laser — •Christina Bogan, Jan-Hendrik Pöld, Patrick Kwee, Benno Willke, and Karsten Danzmann — Albert-Einstein-Institut Hannover

Most high precision measurements require a very stable and robust light source. The gravitational wave detector Advanced LIGO has very strict requirements according to the frequency and power stability as well as to the spatial beam profile of the injected continuous wave 200W Nd:YAG laser. Therefore a combined active and passive stabilization scheme is essential. In order to achieve a TEM00 mode content of more than 98.8% a bow-tie shaped cavity is used as a modecleaner which also supresses beam pointing and power noise at radio frequencies. The laser frequency is stabilized to a high finesse reference cavity. A nested control loop prestabilizes the laser system's power to a relative power noise of $2 * 10^{-8}(\text{Hz})^{-1/2}$ and provides an additional input to achieve a relative power noise of $2 * 10^{-9}(\text{Hz})^{-1/2}$ at the interferometer input.

The concepts and results of the stabilization of the Advanced LIGO laser are presented.

Q 57.97 Thu 16:30 P1

Cold Atom Sagnac Interferometer — •Sven Abend, Peter Berg, Michael Gilowski, Christian Schubert, Gunnar Tackmann, Wolfgang Ertmer, and Ernst M. Rasel — Institut für Quantenoptik, Leibniz Universität Hannover

The project CASI (Cold Atom Sagnac Interferometer) realizes an atomic gyroscope based on matter-wave interferometry with cold Rubidium-87 atoms to precisely measure rotations. The sensitivity of the sensor therefore reaches a resolution of few 10^{-7} rad/s. Besides the reduction of the dominant noise sources, the modification of the conventional Raman beam splitting process to large momentum transfer beam splitter is an approach to increase the sensitivity by enlarging the enclosed interferometric area. The transfer of many photon momenta onto the atomic ensemble is realized via a rapid adiabatic passage in an accelerated optical lattice of two counter propagating light fields. In this poster the first results of the application of large momentum beam splitters in the atomic gyroscope are presented. Furthermore, we report on the present status of the apparatus including the analysis of systematic effects, which lead to the current limitation of the sensor. Finally, future improvements based on the provided analysis of the sensor will be discussed. This work is supported by the DFG, QUEST, and IQS.

Q 57.98 Thu 16:30 P1

Faserlaserbasierter Optischer Kammgenerator unter Schwerelosigkeit (FOKUS) — •Tobias Wilken[1], Matthias Lezius[1], Marc Fischer[2], Theodor W. Hänsch[1] und Ronald Holzwarth[1,2] — [1]Max-Planck-Institut für Quantenoptik, Garching — [2]Menlosystems GmbH, Martinsried

In den letzten Jahren hat sich die Entwicklung des Frequenzkamms als Schlüsseltechnologie der Quantenoptik herausgestellt, ohne die in vielen Bereichen eine ausreichende Kontrolle über das Lichtfeld nicht möglich wäre. Insbesondere bei der Präzisionsspektroskopie oder Frequenzstabilisierung von Lasern ist ein Frequenzkamm heutzutage unverzichtbar geworden.

Um optische Atomuhren oder Atominterferometer auf Satellitenmissionen einsetzen zu können, ist es notwendig, Frequenzkämme soweit zu entwickeln, dass sie sowohl einen Raketenstart als auch die Bedingungen unter Schwerelosigkeit außerhalb unserer Atmosphäre aushalten. Dazu sind im Rahmen des PRIMUS-Projekts im letzen Jahr schon erste Experimente am Fallturm des ZARM in Bremen erfolgreich durchgeführt worden.

Das FOKUS-Projekt zielt nun auf die Konstruktion eines satellitentauglichen Frequenzkamms. Dazu sind Verbesserungen in der Stabilität des Oszillators und des f-$2f$ Interferometers notwendig und die Strahlungshärte der verwendeten Komponenten muss untersucht werden. Erste Ergebnisse werden hier präsentiert.

Q 57.99 Thu 16:30 P1

Systematic frequency shifts in precision spectroscopy of the 1S-2S transition in atomic hydrogen — Christian G. Parthey[1], Arthur Matveev[1], Janis Alnis[1], •Axel Beyer[1], Nikolai Kolachevsky[1], Randolf Pohl[1], Thomas Udem[1], and Theodor W. Hänsch[1,2] — [1]Max-Planck-Institut für Quantenoptik, 85748 Garching — [2]Ludwig-Maximilians-Universität, 80799 München

Precision spectroscopy of the 1S-2S transition in atomic hydrogen has been used to test quantum electro dynamics (QED), determine the Rydberg constant and the proton charge radius. It can also be used to set limits on possible Lorentz-boost invariance violations. Here we report on a new measurement of the 1S-2S transition pushing the uncertainty to the 10^{-15} level. We describe the studied systematic effects in detail.

Q 57.100 Thu 16:30 P1

Stable fibre injectors for ground-based interferometers performing in the picometer stability level — •Lina-Ellen Wittrock, Johanna Bogenstahl, Gerhard Heinzel, and Karsten Danzmann — Max-Planck Institute for Gravitational Physics (Albert-Einstein Institute) Hannover and QUEST, Leibniz University Hannover, Germany

Laser Interferometer often require fiber injectors because the laser is not located directly on the optical bench. Conventional injectors are extremely sensitive in terms of mechanical and thermal stress, which causes problems for interferometric measurements at the picometer stability level. Therefore, their application is not suitable for laser interferometers like the planned space missions LISA (Laser Interferometer Space Antenna) and LISA Pathfinder (LPF). Customized ultra-stable injectors were already developed for implementation on the optical bench of LPF Technology Package at the Institute for Gravitational Research, University of Glasgow.

It has been shown that this improvement of the fiber injectors is not only required for space-bourne but also for ground-based interferometers performing at the picometer stability level. This will be essential for pre-experiments for LISA. The design, construction and implementation of customized ultra-stable fiber injectors for our ground-based experiments will be presented.

Q 57.101 Thu 16:30 P1

Tunable high finesse cavities incorporating a piezoelectric actuator — •Katharina Möhle, Klaus Döringshoff, Moritz Nagel, Evgeny V. Kovalchuk, and Achim Peters — Humboldt-Universität zu Berlin, Institut für Physik, AG Optische Metrologie, Newtonstr. 15, 12489 Berlin

The spaceborne gravitational wave detector LISA (Laser Interferometer Space Antenna) aims to measure gravitational waves with a strain $< 10^{-21}$, which demands an extraordinary frequency stability of the same order of magnitude. Therefore, a three-stage frequency stabilization scheme is proposed, which requires a tunable prestabilization in order to accommodate slow Doppler-shifts caused by yearly variation of the triangular satellite configuration.

For this purpose we investigated the performance of a tunable high finesse optical cavity incorporating a piezoelectric actuator. Our beat measurements reveal a laser frequency noise below 20 $\text{Hz}/\sqrt{\text{Hz}}$ at Fourier frequencies higher than 10 mHz while the cavity can be continuously tuned over more than one free spectral range with a bandwidth of 5 kHz. Thus, our setup fulfills the requirements for a tunable prestabilization for LISA.

Furthermore, we will compare different piezo materials and discuss diverse piezo tunable cavity designs, which account for the requirements given by a space mission.

This work is supported by the German Space Agency DLR with funds provided by the Federal Ministry of Economics and Technology (BMWi) under grant number DLR 50 OQ 0601.

Q 57.102 Thu 16:30 P1

Testing the universality of free fall with a two species atomic gravimeter — •Jonas Hartwig, Dennis Schlippert Schlippert, Ulrich Velte, Daniel Tiarks, Maic Zaiser, Vyacheslav Lebedev, Ernst Rasel, and Wolfgang Ertmer — Institut für Quantenoptik, Hannover

The universality of free fall (UFF) is one of the fundamental postulates of general relativity. It is well measured with macroscopic test masses in experiments like lunar laser ranging and torsion balance. An alternate approach employs atom interferometers which allow for a high precision measurement of forces utilising the quantum nature of matter. A comparison between two atomic isotopes was already demonstrated but only as a proof of principle experiment with limited accuracy.

In the CAPRICE Experiment we are comparing the free fall of potassium and rubidium atoms with a differential atomic gravimeter. This will lead to a precision test of the UFF with two quantum objects We use a 2D/3D MOT system together with an optical dipole trap for trapping and cooling the atomic ensembles. The light fields for the manipulation of both species use the same optical system, thus supressing most of the classical noise sources usually limiting measurement precision in a single species gravimeter.

We will present our first results with the single species rubidium gravimeter and show the progress of the system update to trap and manipulate potassium atoms. We also show our progress in working with an optical dipole trap of 1960 nm wavelength.

Q 57.103 Thu 16:30 P1

High Sensitivity Magnetic Sensing by Ensemble Measurements on Densely Packed Defect Centers in Bulk Diamond — •Thomas Wolf, Merle Becker, Gopalakrishnan Balasubramanian, Fedor Jelezko, and Jörg Wrachtrup — 3rd Physics Institute and Research Center SCOPE, University of Stuttgart

Single, fluorescent defect centers in diamond namely the NV-center have led to numerous scientific contributions in the past in apparently very different areas of application, e.g. quantum computing and spintronics[1], fluorescence and high resolution optical microscopy[2] and magnetometry.

In this work approaches towards high sensitivity magnetometry are presented using ensemble measurements on densely packed NV-centers in bulk diamond at room temperature. Using EPR and optical techniques, the spin states of the NV-centers can be changed and read out. The sensitivity towards external magnetic fields of these measurements (for a single NV-center $3nT/Hz^{\frac{1}{2}}$ has been shown) scales with the square root of the number of NV-centers probed[3]. Ensemble measurements give the opportunity for high sensitivity magnetic sensing with a projected sensitivity in the range of $fT/Hz^{\frac{1}{2}}$ while keeping the dimensions of the sensor small.

[1] P. Neumann et al., Science 320, 5881, 1326-1329 (2008)
[2] G. Balasubramanian et al., Nature 455, 648-651 (2008)
[3] J. Taylor et al., Nature Physics, 4, 810-816 (2008)

Q 57.104 Thu 16:30 P1

A fiber-based femtosecond frequency comb for precision measurements in microgravity — •Andreas Resch, Claus Lämmerzahl, and Sven Herrmann — ZARM Universität Bremen, Am Fallturm, 28359 Bremen

We use a compact fiber-based femtosecond frequency comb in the microgravity environment of the Bremen drop tower at ZARM to explore possible applications in precision experiments, both earthbound and space-based. To this end we have acquired a frequency comb that was designed specifically for the use in a drop tower experiment. The prospective application of this frequency comb is in an experiment that tests the universality of free fall from a differential measurement of a dual species atom interferometer. Due to the extended time of free fall available in the microgravity environment of the drop tower, and ultimately on board the International Space Station, the sensitivity of such an atom interferometer will be significantly enhanced as compared to earthbound laboratory experiments. In order to do a precision measurement of the differential phase of the atom interferometers we will use the frequency comb in two ways: First to lock the lasers at 780 nm and 767 nm to the comb's lines, secondly to generate a microwave signal, from which the Raman splitting frequencies can be derived. In order to generate the low-noise microwave signal, the frequency comb will be stabilized to an optical high-finesse cavity. We acknowledge support by the German Space Agency DLR with funds provided by the Federal Ministry of Economics and Technology (BMWi) under grant number DLR 50 WM 0842.

Q 57.105 Thu 16:30 P1

Towards an optical lattice-based magnesium frequency standard — •Klaus Zipfel, Matthias Riedmann, Jan Friebe, Hrishikesh Kelkar, Temmo Wübbena, Andre Kulosa, Andre Pape, Dominika Fim, Wolfgang Ertmer, and Ernst Maria Rasel — Institut für Quantenoptik, Leibniz Universität Hannover, Welfengarten 1, 30167 Hannover

Optical atomic clocks have large potential regarding accuracy and stability compared to the best microwave clocks. Alkaline-earth magnesium (Mg) is an interesting candidate for a future neutral atom optical clock because of its low sensitivity to blackbody radiation, which is currently limiting the accuracy of state-of-the-art Sr lattice clocks.

At the magic wavelength of Mg, which has been predicted to be at 463 nm, the differential AC-Stark shift of the strictly forbidden $^1S_0 \rightarrow {}^3P_0$ clock transition cancels out. Furthermore, the tight confinement of the atoms in the lattice will enable us to reach the Lamb-Dicke regime, allowing first order Doppler-free spectroscopy.

As a precursor, we loaded Mg atoms in an optical dipole trap at 1064 nm. Using a continuous loading scheme, we reach up to 10^5 atoms at an average temperature of 100 μK. Currently, we investigate to create an optical lattice inside an optical resonator to enhance the trap depth and the loading of this lattice.

Q 57.106 Thu 16:30 P1

LISA Backlinkfiber - Return loss of a polarization maintaining single-mode optical fiber — •Jan Rybizki, Roland Fleddermann, Michael Tröbs, Gerhard Heinzel, and Karsten Danzmann — Max-Planck Institute for Gravitational Physics (Albert-Einstein-Institute) Hannover and QUEST, Leibniz University Hannover

The Laser Interferometer Space Antenna (LISA) mission by ESA and NASA for the detection of gravitational waves in the frequency range from 0.1 mHz to 1 Hz requires optical fibers for the intrasatellite transfer of light between the optical benches.

The so called Backlinkfiber introduces new noise mostly by its own backreflection (return loss) which effectively looks like a non-reciprocal phase shift and thus enters the final science measurement.

A setup to quantify these reflections for different fibers and the results with implications on possible solutions to minimize the noise will be presented.

Q 57.107 Thu 16:30 P1

Towards an Ultra-Stable Optical Sapphire Cavity System for Testing Lorentz Invariance — •Moritz Nagel, Katharina Möhle, Klaus Döringshoff, Evgeny V. Kovalchuk, and Achim Peters — Humboldt-Universität zu Berlin, Institut für Physik, AG Optische Metrologie, Newtonstr. 15, 12489 Berlin

We present a design for an ultra-stable cryogenically cooled sapphire optical cavity system, with a fractional frequency stability better than 10^{-16} at one second integration. This so far unrealized stability in optical resonator systems could be used to enhance a broad range of experimental and technical applications, e.g. high-precision spectroscopy or deep-space communication.

We plan to use the ultra-stable cavities to perform the best laboratory-based test of Lorentz invariance. The cavities will be arranged in a Michelson-Morley configuration and continuously rotated for more than one year using a custom-made high-precision low noise turntable system. The sensitivity of this setup to violations of Lorentz invariance should be in the 10^{-19} to 10^{-20} regime, corresponding to more than a 100-fold improvement in the precision of modern Michelson-Morley type experiments. Furthermore, ultra-stable cryogenic microwave whispering gallery resonators will be added to the experiment in collaboration with the University of Western Australia. With this co-rotating microwave and optical resonator setup we will for the first time be able to search for new types of Lorentz violating signals.

Q 57.108 Thu 16:30 P1

A compact Yb optical lattice clock — •Charbel Abou Jaoudeh, Gregor Mura, Tobias Franzen, Taner Esat, Cristian Bruni, and Axel Görlitz — Institut für Experimentalphysik, Universitätstr. 1, 40225 Düsseldorf

Optical clocks using neutral atoms hold the promise to eventually reach an inaccuracy at a level of 10^{-18}. Here we report on the development of a transportable source of ultracold Yb atoms for an optical lattice clock. All laser systems in the compact apparatus are diode-based. We have already implemented the first cooling stage using blue laser diodes at 399 nm and realized a magnetooptical trap (MOT) with more than 10^7 atoms. Successful transfer of 20 % from the bosonic ^{174}Yb and fermionic ^{171}Yb MOT into the second stage MOT operating on the narrow $6^1S_0 \rightarrow 6^3P_1$ transition at 556 nm and further cooling of the atoms to temperatures of 20 μK has also been achieved. The next step will be to load the atoms into a 1D optical lattice at the magic wavelength of 759 nm which is formed in a resonator inside the vacuum chamber. The special design of the lattice setup allows for a large-volume optical lattice with a diameter of 155 μm and a potential depth of 300 μK if 300 mW of radiation from a tapered diode laser are coupled into the resonator.

Q 57.109 Thu 16:30 P1

A Modern Michelson-Morley Experiment Using Cryogenic Sapphire Microwave Oscillators — •Stephen Parker[1], Paul Stanwix[1], Michael Tobar[1], John Hartnett[1], Eugene Ivanov[1], Moritz Nagel[2], and Achim Peters[2] — [1]School of Physics, The University Of Western Australia, Crawley 6009, Western Australia, Australia — [2]Humboldt-Universität zu Berlin, Institut für Physik, AG Optische Metrologie, Newtonstr. 15, 12489 Berlin

Lorentz Invariance is a fundamental component of General Relativity and the Standard Model of Particle Physics.We describe the details of our latest Michelson-Morley experiment that has recently been set up at Humboldt University in Berlin. The experiment compares the resonant frequencies of two orthogonally aligned cryogenic sapphire microwave oscillators that are actively rotated in the laboratory. A standing wave whispering gallery mode is excited in the cryogenic sapphire oscillators which resonates at 13 GHz. They exhibit a frequency stability on the order of 10^{-16} for integration times from 10 - 40 seconds (approximately the period of active rotation). This low stability increases the sensitivity of the experiment to violations of Lorentz Invariance which we express as bounds on coefficients from the Standard Model Extension. The experiment will be run for a full year ending in December 2011, after which it will be combined with a set of optical sapphire resonators for a joint experiment with the optical metrology group at Humboldt University.