Q 34: Poster 1

Time: Tuesday 16:30–19:00 Location: Poster.I+II

Q 34.1 Tue 16:30 Poster.I+II

Design of an LQG controller to stabilise an optical resonator — •Dirk Schütte, Maximilian Wimmer, Timo Denker, Michèle Heurs, and Karsten Danzmann — Max-Planck-Institut für Gravitationsphysik, Hannover, Deutschland

For many quantum optical systems a high controllability is required. A basic example (the "work horse") is locking an optical resonator to a laser or vice versa. We show that systematic modern control techniques (here linear-quadratic Gaussian control including Kalman filtering) can be applied to achieve frequency locking of a cavity to a laser. The more complex the quantum system becomes the more potential pay-off is gained by a systematic controller implementation. For this reason a successful design of an LQG feedback controller can lead the way to extremely stable systems consisting of multiple / nested feedback loops with multiple actuators and sensors (MIMO systems). We present the design process of an LQG controller with additional integral action, as well as the results of its application to locking a ring cavity to a laser.

Q 34.2 Tue 16:30 Poster.I+II

Enlighten the AEI 10m Prototype Interferometer — •Thimotheus Alig for the AEI 10m Prototype Team — Leibniz Universität Hannover und Max-Planck-Institut für Gravitationsphysik (AEI)

An important link to the understanding of the transition between quantum mechanics and the physics of macroscopic objects is the investigation of macroscopic quantum systems. For this reason and for the improvement of gravitational-wave detectors, the AEI 10m Prototype Interferometer is being set up at the Max-Planck-Institute for Gravitational Physics in Hannover. It is a Michelson interferometer extending over three benches inside a vacuum system with an arm length of about 10m. The macroscopic quantum system will be composed of the laser light and 100g heavy mirrors, whose positions are to be measured by the interferometer at the Standard Quantum Limit.

The light for the interferometer is generated by a monolithic nonplanar ring oscillator outside the vacuum at a wavelength of 1064nm and is then amplified to a maximum output power of 35W. It is sent through a 5m long photonic crystal fibre into the vacuum system. Due to the fiber length and the high laser power the Brillouin scattering in the fiber is the limiting factor of the optical power for the interferometer.

This talk deals with the provision of the laser light for the interferometer with a focus on the transmission of the light through the fiber.

Q 34.3 Tue 16:30 Poster.I+II

Kohärente Feed-Forward-Regelung von Quantensystemen — •Maximilian Wimmer, Timo Denker, Dirk Schütte, Michèle Heurs und Karsten Danzmann — Albert Einstein Institut Hannover, Max Planck Institut für Gravitationsphysik

Strahlungsdruckrauschen wird eine der dominanten Rauschquellen in zukünftigen Gravitationswellendetektoren sein. Wir stellen Konzepte für die experimentelle Umsetzung einer kohärenten Feed-Forward Regelung vor, mit der dieses Rauschen ohne direkte Messung eliminiert werden soll. Die Kopplung zweier Resonatoren über nichtlineare Prozesse erzeugt einen Antirauschprozess, welcher dem Strahlungsdruckrauschen entgegengesetzt ist und mit diesem destruktiv interferiert. Dies soll erst in Laborexperimenten getestet werden, um später in größeren Experimenten wie zum Beispiel dem AEI-10m-Prototypen zur Anwendung zu kommen.

Q 34.4 Tue 16:30 Poster.I+II

Coating thermal noise interferometer — •Tobias Westphal for the AEI 10m Prototype team — Max-Planck-Institute for Gravitational Physics (Albert-Einstein-Institut) and Centre for Quantum Engineering and Space Time Research, Leibniz University Hannover

Coating thermal noise (CTN) is a significant noise source for high precision experiments and metrology. It arises from mechanical losses in the dielectric coatings put onto mirrors to achieve high reflectivity. Deeper understanding and verification of its theory requires direct (off-resonant) observation.

The AEI 10 m Prototype facility is probably the best suited environment for this kind of experiment in a frequency range most important for earth bound gravitational wave detectors. A pre-isolated platform shows three to four orders of magnitude attenuated seismic noise inside ultra-high vacuum. Up to 10 W highly stabilized (frequency as well as amplitude) laser power at 1064 nm will be available for experiments.

In this talk the CTN- interferometer being at the transition from design to construction phase will be presented. The range solely limited by CTN is designed to reach from 10 Hz to about 50 kHz, limited by seismic noise at low frequencies and shot noise (photon counting noise) at high frequencies.

Q 34.5 Tue 16:30 Poster.I+II

Deep phase modulation interferometry — •Thomas Schwarze, Felipe Guzman Cervantes, Oliver Gerberding, Gerhard Heinzel, and Karsten Danzmann — Albert-Einstein-Institut Hannover

We present our research plan and initial results on the development of a dedicated hardware modulation system for the Deep phase modulation interferometry technique. A sinusoidal modulation is applied through a ring piezo-electric actuator to one arm of a Mach-Zehnder interferometer in order to reach large modulation depths of the order of 10-20 rad. The interferometer phase is extracted by a complex fit to the harmonic amplitudes of the modulation frequency. A first prototype uses the first 10 harmonic amplitudes and has demonstrated length and angular measurement sensitivities at millihertz frequencies of about 20 pm/rtHz and 10 nrad/rtHz, respectively. Initial observations showed that the phase noise has a dependency on the modulation depth. Our research focus on the development of a digital modulation system based on Field Programmable Gate Arrays to perform multi-frequency single-bin discrete Fourier transforms at the required harmonic amplitudes. A dedicated floating-point microprocessor will also be included to perform the complex fit computations for the phase extraction. A digital signal synthesizer is included in the design and will use the fit output as input parameters for active control loops of, for example, the modulation depth, modulation frequency, and interferometer phase state.

Q 34.6 Tue 16:30 Poster.I+II

From Maxwell Equations to Bose-Einstein Condensation of Photons — •Tobias Rexin[1], Carsten Henkel[1], and Axel Pelster[2] — [1]Institut für Physik und Astronomie, Universität Potsdam, Germany — [2]Hanse-Wissenschaftskolleg, Delmenhorst, Germany

Light confined in a microcavity [1] is described by Maxwell's equations with appropriate boundary conditions. A careful analysis of the corresponding boundary value problem in oblate spheroidal coordinates provides a systematic approach to determine the underlying mode functions. In the paraxial approximation, this three-dimensional microcavity problem can be reduced to an effective two-dimensional trapped massive Bose gas. This result supports the heuristic derivation of Ref. [2], where even the Bose-Einstein condensation of these massive photons was observed. We present recent calculations of the mode structure and correlation functions in thermodynamic equilibrium.
[1] J. Klaers, F. Vewinger, and M. Weitz, Nature Physics **6**, 512 (2010).
[2] J. Klaers, J. Schmitt, F. Vewinger, and M. Weitz, Nature **468**, 545 (2010).

Q 34.7 Tue 16:30 Poster.I+II

Deviations from Gross-Pitaevskii dynamics for Bose-Einstein condensates in double-well potentials — •Bettina Gertjerenken[1], Stephan Arlinghaus[1], Niklas Teichmann[1], and Christoph Weiss[1,2] — [1]Institut für Physik, Carl von Ossietzky Universität, D-26111 Oldenburg, Germany — [2]Department of Physics, Durham University, Durham DH1 3LE, United Kingdom

For the description of Bose-Einstein condensates often the Gross-Pitaevskii equation is used. While giving a good description of experiments in a lot of situations there are cases where deviations in the N-particle dynamics occur [1]. Hence, the validity of this approach should be investigated thoroughly: for a Bose-Einstein condensate in a double-well potential we observe deviations of the Gross-Pitaevskii dynamics from N-particle dynamics for large particle numbers on experimentally feasible time scales.

[1] B. Gertjerenken *et al*, Phys. Rev. A **82**, 023620 (2010).

Q 34.8 Tue 16:30 Poster.I+II

Bose-Einstein condensates in optical micro-potentials — •Johannes Küber, Thomas Lauber, Felix Schmaltz, and Gerhard Birkl — Institut für Angewandte Physik, Technische Universität Darmstadt, Schlossgartenstraße 7, 64289 Darmstadt

We present an optimized loading and evaporation strategy for the all-optical generation of Bose-Einstein condensates (BECs) of rubidium in a crossed dipole trap with a multi-frequency laser at 1070nm. We characterize highly power-dependent two-body losses resulting from optical pumping to higher-energy hyperfine states and show an efficient path to evaporative cooling to reach a BEC of 25000 Rb atoms [1].

Our experiment demonstrates the combination of various attractive and repulsive trapping potentials to shape a toroidal waveguide. We use conical refraction produced by a transparent biaxial crystal to create two ring-shaped repulsive optical potentials with a dark ring in between. We combine them with an attractive light sheet to create a toroidal trap.

In our experiments we use the toroidal potential to trap atoms loaded from the crossed dipole trap and guide them along the ring structure. Using a one-dimensional optical lattice we accelerate the condensed atoms and observe cycling of the atoms in the trapping potential.

[1] T. Lauber *et al., Phys. Rev. A* **84**, 043641, (2011).

Q 34.9 Tue 16:30 Poster.I+II

Bose-Einstein Condensation of Photons with Dye Quantum Dots in an Optical Microcavity — •David Dung, Tobias Damm, Julian Schmitt, Jan Klärs, Frank Vewinger, and Martin Weitz — Institute for Applied Physics (IAP), Universität Bonn

In former work Bose-Einstein condensation of photons in a dye-filled optical microcavity has been realized [1]. In this experiment, a number-conserving thermalization process is achieved by multiple absorption and fluorescence of dye-molecules. The microcavity creates a confining potential, providing a non-trivial ground state and leading to a non-vanishing effective photon mass. Formally, the system is equivalent to a two-dimensional gas of trapped, massive bosons.

We here report on current efforts to replace the so far used dye solution by dye quantum dots. The goal here is to increase the photostability of the light-matter thermalisation medium. Because quantum dots are commercially available encabsulated and thus shielded from the enviroment, they allow for a higher photostability than usual dye media. We expect that dye quantum dots within a tracer-matrix also offer the possibility to realize solid state material filled microcavities. This would be a first step towards technical applications of a photonic BEC.

[1] Klaers et al., *Nature* **468**, 545 (2010).

Q 34.10 Tue 16:30 Poster.I+II

Condensate Depletion due to Correlated Disorder — •Christopher Gaul[1] and Cord A. Müller[2] — [1]GISC, Departamento de Física de Materiales, Universidad Complutense, E-28040 Madrid, Spain — [2]Centre for Quantum Technologies, National University of Singapore, Singapore 117543, Singapore

We study interacting bosons at low temperature in spatially correlated disorder potentials. In the noninteracting case all particles condense into the lowest single-particle state. Due to interactions, however, a certain fraction of particles is outside the condensate, even at zero temperature and in the homogeneous case.

The Bogoliubov ansatz splits $\hat{\Psi}(\mathbf{r})$ into the (mean-field) condensate $\Phi(\mathbf{r})$ and the quantum fluctuations $\delta\hat{\psi}(\mathbf{r})$. In the first step one neglects the quantum fluctuations. The Gross-Pitaevskii equation describes how the condensate is deformed by the disorder potential. This is not yet a depletion of the condensate mode, which is still populated by all particles. We then consider the quantum fluctuations. By a Bogoliubov expansion around the deformed mean-field condensate, we derive the fundamental Hamiltonian for elementary excitations, including an analytical formulation in the case of weak disorder. From this, we calculate the sound velocity as well as the quantum depletion of the condensate due to interaction and disorder. We cover the relevant dimensions $d = 1, 2, 3$ and arbitrary correlation lengths, including the limit of uncorrelated disorder.

C. Gaul and C.A. Müller PRA, 83, 063629 (2011)

C. Gaul and C.A. Müller arXiv:1009.5448

Q 34.11 Tue 16:30 Poster.I+II

Quantum turbulence in an ultracold Bose gas — •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

Turbulence in an ultracold Bose gas, in one, two and three spatial dimensions, is investigated 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. It is explained, how the infrared power laws can be understood from the statistics of vortices as well as from an analytic field-theoretic approach based on the 2PI effective action. Possible ways to experimentally study strong turbulence phenomena with ultracold atomic gases are outlined.

Q 34.12 Tue 16:30 Poster.I+II

Solitons in ultracold bose gases out of equilibrium — •Sebastian Erne[1,2], Boris Nowak[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

We investigate the dynamics of BECs out of equilibrium in one spatial dimension by statistical simulations using the classical field equations. Special focus is set on the time evolution of the soliton formation and the characterisation of the quasi-steady solitonic state by measurements of characteristic quantities such as the density-density correlation, the spectrum of the one particle momentum distribution and the interference of condensates during the solitonic state. In particular we investigate the collision of multiple BECs released from an optical lattice and the interference of two coherent splitted one dimensional condensates. The results give insight into the dynamics and impacts of solitons in these systems.

Q 34.13 Tue 16:30 Poster.I+II

Using hybrid systems to probe BEC features — •Mathias Schneider and Reinhold Walser — Institut für Angewandte Physik, Technische Universität Darmstadt, D-62289, Germany

Hybrid systems like micro-mechanical objects immersed into Bose-Einstein condensates (BEC) have recently been object to intense research. Among the many effects that can be observed from this kind of configuration, one always encounters increased loss of atoms from the condensate. Employing objects which are small compared to the cloud size (e.g. carbon nanotubes, fullerenes, ions), atom loss is limited to a finite area. Thus, these objects can be used to burn "holes" into the BEC density profile. We investigate the dynamics of a condensate being subject to localized dissipation. In particular, we are interested in how the micro-mechanical object can be utilized as a probe for BEC features.

Q 34.14 Tue 16:30 Poster.I+II

Kopplung von Testmassenverkippung in das longitudinale Signal in der Präzisionslaserinterferometrie — •Sandra Weber, Karsten Danzmann, Gerhard Heinzel, Michael Troebs und Johanna Bogenstahl — AEI Hannover

Laser Interferometer Space Antenna (LISA) hat sich zum Ziel gesetzt, durch Messung von Längenänderungen zwischen freifliegenden Testmassen Gravitationswellen mithilfe von Präzisionslaserinterferometrie zu messen. Die dazu notwendigen Interferometer befinden sich auf der sogenannten optischen Bank.

In LISA kommt es zu einer Kreuzkopplung zwischen Verkippungen dieser Testmassen und dem longitudinalen Signal- dies ist eine Rauschquelle. Ziel ist es, diese Kopplung zu eliminieren, beziehungsweise so stark zu reduzieren, dass sie den Anforderungen von LISA genügen. Dazu dienen Abbildungssysteme auf der optischen Bank.

Mithilfe eines homodynen Mach-Zehnder Interferometers werden diese Abbildungssysteme charakterisiert. Die Ergebnisse und notwendigen Voraussetzungen werden im Vortrag dargestellt.

Q 34.15 Tue 16:30 Poster.I+II

Coherence of single spins in diamond in nanometer distance to the surface — •Tobias Staudacher[1,3], Fazhan Shi[1,3], Sébastien Pezzagna[4], Jan Meijer[4], Alexander Petrajtis[1], Boris Naydenov[5], Jiangfeng Du[3], Andrej Denisenko[1], Friedemann Reinhard[1], and Jörg Wrachtrup[1] — [1]3. Institute of Physics and Research Center SCOPE, University Stuttgart, D-70550 Stuttgart — [2]International Max Planck Research School for Advanced Materials, D-70569 Stuttgart — [3]Hefei National Laboratory for Physical Sciences at the Microscale and Department of Modern Physics, University of Science and Technology of China, Hefei, Anhui 230026 — [4]RUBION, Ruhr-Universität Bochum, D-44780 Bochum — [5]Institut für Quantenoptik, Universität Ulm, D-89069 Ulm

The nitrogen vacancy (NV) center in diamond seems to be an ideal candidate for ultrasensitive nanoscale magnetometry, due to the possibility to prepare and detect its spin state by optical means as well as its long coherence times. For the detection of spins outside the diamond lattice, reliable spin properties in the close vicinity to the surface are required. The proximity to the surface degrades the coherence, and hence the field sensitivity is reduced in exchange for a smaller separation between the NVs and an external spin. We investigate the effect of the surface proximity on the coherence of single NV centers, which have been implanted a few nanometers below the diamond surface. The experimental methods include dynamical decoupling sequences, double electron electron resonance techniques and varying surface treatments before and after the implantation process.

Q 34.16 Tue 16:30 Poster.I+II

Evaporation and expansion of ultracold gases calculated on GPUs — •Roman Nolte — TU Darmstadt

Evaporative cooling is the essential method for attaining quantum degeneracy. In the Quantus experiment [1], which explores quantum gases in microgravity the details of this process are of greater interest due to limited time. As the experiment itself also investigates and utilizes the expansion properties their theoretical description becomes of interest too.

In this contribution we present the predictions of our N-particle molecular dynamics simulation performed on graphic cards both describing evaporation and free expansion properties of ultracold gases and compare them to the results of the aforementioned experiment.

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

Q 34.17 Tue 16:30 Poster.I+II

High Resolution Probing and Manipulation of Ultra Cold Quantum Gases — •Felix Stubenrauch, Andreas Vogler, Ralf Labouvie, Peter Würtz, Giovanni Barontini, Vera Guarrera, and Herwig Ott — Fachbereich Physik, Technische Universität Kaiserslautern

The technique of scanning electron microscopy allows for the investigation of solid surfaces and structures with a spatial resolution of a few nanometers. Extending the application of this tool to a cloud of ultracold atoms, we obtain a novel way to image and manipulate the gaseous target, characterized by high spatial resolution and by single atom sensitivity. A focussed electron beam is moved over the cloud and ionizes the atoms by electron impact ionization. The produced ions are subsequently extracted and detected. We successfully employed the technique for in situ observation of temporal correlations in a cold thermal cloud. The electron beam can also be used to locally introduce losses, thus paving the way to investigate dissipative processes in quantum gases and to generate topological defects.

Q 34.18 Tue 16:30 Poster.I+II

General Relativistic Mean-Field 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 (BECs) 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 first realization of BECs in microgravity at the ZARM droptower in Bremen by the QUANTUS collaboration [1], it is now possible to perform free-fall experiments over large distances of 100 m and long times of 5–10 s. After the detailed non-relativistic modeling [2], it has become relevant to look into a general relativistic description of free-falling BECs and to quantify the arising relativistic corrections.

In this contribution, we present a fully covariant, general relativistic, mean-field description of an expanding Bose Einstein condensate, traveling along an arbitrary time-like worldline of a given background space-time metric.

[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 34.19 Tue 16:30 Poster.I+II

Zerfall und Dynamik von Doublonen im Bose-Hubbard-Modell auf einem hexagonalen Gitter — •Holger Niehus und Daniela Pfannkuche — I. Institut für Theoretische Physik, Universität Hamburg

Ultrakalte Quantengase in optischen Gittern lassen sich mit hoher Genauigkeit durch das Bose-Hubbard-Modell beschreiben. Fortschrittliche experimentelle Techniken erlauben die gezielte Erzeugung von Doublon-Loch-Paaren, also je eines doppelt und eines unbesetzten Gitterplatzes. Im Bose-Hubbard-Modell existiert trotz der repulsiven Wechselwirkung der Atome ein Regime, in dem diese Anregungen stabil sind.[1] Die Doublonen tragen die Wechselwirkungsenergie U, welche unter Berücksichtigung der Energieerhaltung beim Zerfall in kinetische Energie der beteiligten Atome umgewandelt werden muss. Das unterste Hubbard-Band hat jedoch nur eine Bandbreite von $6J$. Daher ist für große U/J der direkte Zerfall unterdrückt und nur über Streuung an weiteren Atomen im Gitter möglich.

Im Fokus unserer theoretischen Untersuchung steht der Einfluss der hexagonalen Gittersymmetrie[2] auf die Dynamik und den Zerfall der Doublonen. Wir berechnen unter Annahme von periodischen Randbedingungen mithilfe exakter Diagonalisierung die vollständige korrelierte Zeitentwicklung eines Doublon-Loch-Paares für Zellen mit wenigen Gitterplätzen und Füllungsfaktor 1.

[1] K. Winkler et al., Nature 441 (853-856)
[2] P. Soltan-Panahi et al., Nature Physics 7 (434-440)

Q 34.20 Tue 16:30 Poster.I+II

Feshbach Resonances in ^{40}K — •Jasper Simon Krauser, Jannes Heinze, Nick Fläschner, Sören Götze, Christoph Becker, and Klaus Sengstock — Universität Hamburg, Institut für Laser-Physik, Luruper Chaussee 149, 22761 Hamburg, Germany

Quantum gases offer a wide range of applications for quantum simulation due to the high tunability of the crucial experimental parameters. Especially Feshbach resonances have been proven to be an essential tool to control the atomic interaction in ultracold quantum gases and have found numerous applications in Bose-Einstein condensates as well as in degenerate Fermi gases. Here, we explore Feshbach resonances in different homonuclear mixtures of ^{40}K within the $f = 9/2$ hyperfine manifold. In the experiment, we prepare binary spin mixtures in an optical dipole trap and investigate atomic losses at different magnetic fields. We study mixtures, which are stable or unstable against spin relaxations, and observe a variety of Feshbach resonances in good agreement with theoretical predictions. Within stable channels, the resonances are associated with low loss rates. In the spin mixture $m_{f_1,f_2} = 1/2, -1/2$ a resonance at 384.5 G with a width of 26 G is reported, which could serve as an intriguing tool for future experiments due to its large width. Combining different Feshbach resonances opens the route to study triple mixtures of Potassium with independent control of the interaction.

Q 34.21 Tue 16:30 Poster.I+II

Towards local probing of ultracold Fermi gases — •Kai Morgener, Wolf Weimer, Jan Henning Drewes, Niels Strohmaier, and Henning Moritz — Universität Hamburg, Institut für Laserphysik, Luruper Chaussee 149, 22761 Hamburg

Ultracold fermionic gases are an ideal model system for the study of quantum many-body phenomena. Of particular interest are two-dimensional strongly correlated systems which can exhibit superfluidity and Berezinskii-Kosterlitz-Thouless-type transitions.

Here we present our new experimental setup aimed at studying two-dimensional strongly interacting Fermi gases. Lithium atoms are cooled all-optically using an in vacuo bow-tie resonator for high transfer and cooling efficiency. The quantum degenerate gas will then be placed between two high resolution microscope objectives for local readout and control. The present status of the experiment will be shown.

Q 34.22 Tue 16:30 Poster.I+II

Strategy for the optical preperation of an ultracold Bose-Fermi mixture of Li and Cs — •Robert Heck, Marc Repp, Rico Pires, Juris Ulmanis, Stefan Schmidt, Romain Müller, and Matthias Weidemüller — Physikalisches Institut, Ruprecht-Karls-Universität Heidelberg, Heidelberg, Germany

The mixture of ultracold ^{133}Cs and ^{6}Li atoms and molecules close to quantum degeneracy permits to study many different aspects of few and many body physics by precise tuning and characterization of interactions between the different species via magnetic fields (Feshbach resonances). Additionally, Li and Cs form the system with the highest mass imbalance between all alkali combinations leading to the appearance of universal Efimov states [1,2] with the smallest scaling factor of 4.88 for the ^{133}Cs$_2$^{6}Li trimer [3] (22.7 in case of homonuclear mixtures).

In this poster we present the experimental approach and the current status of our experimental apparatus for cooling Li and Cs atoms to phase-space densities close to quantum degeneracy. The atoms emitted from an oven are decelerated by a double-species Zeeman slower and loaded into MOTs. The Cs atoms are further cooled via Raman sideband cooling. Forced evaporative cooling in two seperated dipole traps will lead to a BEC of Cs and a quantum degenerate Fermi gas of Li.

[1] V. Efimov, Sov. J. Nuc. Phys. 12, 589 (1971)
[2] E. Braaten & H.-W. Hammer, Annals of Physics 322, 120 (2007)
[3] J. P. D'Incao & B. D. Esry, Phys. Rev. A 73, 030703 (2006)

Q 34.23 Tue 16:30 Poster.I+II

Multi-component fermionic quantum gases in optical lattices — •Jannes Heinze, Jasper Simon Krauser, Nick Fläschner, Sören Götze, Christoph Becker, and Klaus Sengstock — Universität Hamburg, Institut für Laser-Physik, Luruper Chaussee 149, 22761 Hamburg, Germany

The alignment of electron-spins in materials constitutes the microscopic origin of their magnetic properties. Understanding the resulting magnetic quantum phases and their microscopic structure is of high interest. Promising progress has been achieved in this direction using ultracold quantum gases in optical lattices which provide widely tunable experimental systems. Here, we study the properties of multi-component fermionic quantum gases in an optical lattice. In contrast to real solids with spin-1/2 electrons, we produce interacting spin mixtures of potassium atoms allowing for the realization of a higher effective spin. We observe the quantum dynamics of excited states and identify different regimes. The findings are explained within a theoretical two-particle model including the atomic interaction. Our results open new perspectives to study magnetism of fermionic lattice systems beyond conventional spin-1/2 systems.

Q 34.24 Tue 16:30 Poster.I+II

Elastic and Inelastic Collisions of Single Cs Atoms in an Ultracold Rb Cloud — •Farina Kindermann[2,1], Nicolas Spethmann[1], Dieter Meschede[1], and Artur Widera[2,1] — [1]Institut für angewandte Physik, Wegelerstr. 8, 53115 Bonn — [2]TU Kaiserslautern, FB Physik, Erwin-Schrödinger-Str. 46, 67663 Kaiserslautern

Ultracold gases doped with impurity atoms are promising hybrid systems that pave the way for investigation of a series of novel and interesting scenarios: They can be employed for studying polaron physics, the impurity atoms can act as coherent probes for the many-body system, and the coherent cooling of neutral atoms containing quantum information has been proposed. Here, we immerse single and few Cs atoms into an ultracold Rb cloud. Elastic collisions lead to rapid thermalization of both sub-systems, while inelastic collisions lead to a loss of Cs from the trap. When thermalized,the impurity atom is localized inside the Rb gas. The ultracold Rb gas remains effectively unaffected by the interaction with the Cs impurity atoms. The poster will present details of the experimental setup, sequence and data analysis needed to extract the interspecies scattering length and three-body loss coefficient from the thermalization dynamics and loss rates measured.

Q 34.25 Tue 16:30 Poster.I+II

Generation of non-classical states of matter using spinor dynamics — Bernd Lücke[1], Manuel Scherer[1], Jens Kruse[1], Luca Pezze[2], Frank Deuretzbacher[3], Philipp Hyllus[4], Oliver Topic[1], •Jan Peise[1], Wolfgang Ertmer[1], Jan Arlt[5], Luis Santos[3], Augusto Smerzi[2], and Carsten Klempt[1] — [1]Institut für Quantenoptik, Leibniz Universität Hannover, Hannover, Germany — [2]Istituto Nazionale di Ottica (INO), Consiglio Nazionale delle Ricerche (CNR), and European Laboratory for Non-Linear Spectroscopy (LENS), Firenze, Italy — [3]Institut für Theoretische Physik, Leibniz Universität Hannover, Hannover, Germany — [4]Department of Theoretical Physics, The University of the Basque Country, Bilbao, Spain — [5]Center for Quantum Optics (QUANTOP), Institut for Fysik og Astronomi, Aarhus Universitet, Århus C, Denmark

In optics, parametric amplification is an important tool to generate non-classical states of light and investigate phenomena such as squeezing and entanglement. This technique can be transferred to matter-waves by using spinor dynamics in Bose-Einstein condensates. To generate non-classical states of matter we use spin changing collisions in a BEC initially prepared in the $m_F = 0$ state. These collisions may lead to the creation of correlated pairs of atoms with spin up and down ($m_F = \pm 1$). The pair production implies a reduced fluctuation in the population imbalance in $m_F = \pm 1$. We measured the corresponding variance to be well below the shot-noise limit (-6.9 dB). The measurements are in agreement with the properties of a twin-Fock state and thus point towards interferometry at the Heisenberg limit.

Q 34.26 Tue 16:30 Poster.I+II

Towards ultra-cold Bose-Fermi experiments in 2D optical lattices — •Nadine Meyer[1,2], Michael Holinsky[1], Mathis Baumert[1], Marisa Perea Ortiz[1], Kai Bongs[1], and Jochen Kronjäger[1] — [1]School of Physics and Astronomy, University of Birmingham, UK — [2]Institute for Laser Physics, University of Hamburg, Germany

Progress towards a new Bose-Fermi 2D quantum gas mixture experiment of rubidium and potassium is presented. A dual microscope objective setup will be used to achieve in situ single site resolution for manipulation and detection in optical lattices. In order to investigate the phase diagrams of different lattices geometries with superimposed arbitrarily shaped optical potentials, in particular disorder induced phases, a spatial light modulator (SLM) will be used. Transport of atoms between separate 3D MOT and science chambers will be provided by magnetic coils moving on a linear actuator, with additional chambers allowing the mixing of arbitrary species in the future. New technologies for ultra-high vacuum, ultra-stable laser systems and compact high power magnetic coils are presented along with the progress towards magnetic transport of a thermal cloud of rubidium. We acknowledge support by EPSRC under grants EP/E036473/1 and EP/H009914/1

Q 34.27 Tue 16:30 Poster.I+II

Beyond mean-field dynamics in open Bose-Hubbard chains — •Anton Ivanov, Georgios Kordas, and Sandro Wimberger — Institut für theoretische Physik und HGSFP, Universität Heidelberg

We analyze the dissipative dynamics of bosonic quantum gases beyond the mean-field approximation. Our system consists of a one dimensional Bose-Hubbard chain coupled to a bosonic reservoir and we allow the exchange of energy and particles with the reservoir. For this system we derive a Master equation in Lindblad form which can be solved exactly in some limiting cases. Numerical solutions are provided including interparticle correlations beyond mean-field. With this machinary we investigate the non-equilibrium transport of particles across the chain dependending on interactions and reservoir parameters.

Q 34.28 Tue 16:30 Poster.I+II

Dipolar Bose-Einstein Condensates in Weak Anisotropic Disorder Potentials — •Branko Nikolić[1], Antun Balaž[1], and Axel Pelster[2] — [1]Scientific Computing Laboratory, Institute of Physics Belgrade, University of Belgrade, Serbia — [2]Hanse-Wissenschaftskolleg, Delmenhorst, Germany

We explore the peculiar properties of ultracold Bose gases which emerge from the delicate interplay between an anisotropic two-particle interaction and an anisotropic random potential. To this end we consider homogeneous Bose-Einstein condensates with both dipolar and contact interaction in weak disorder potentials which are characterized by an anisotropic Lorentzian correlation distribution in Fourier space. Solving perturbatively the Gross-Pitaevskii equation to second order with respect to the disorder potential allows to calculate analytically the disorder-ensemble averages for the condensate and superfluid depletion, the equation of state, and the sound velocity. Apart from reproducing previous special cases [1,2], these properties show characteristic anisotropies which arise from the formation of fragmented dipolar condensates in the minima of the anisotropic disorder potential.

[1] K. Huang and H. F. Meng, Phys. Rev. Lett. **69**, 644 (1992).
[2] C. Krumnow and A. Pelster, Phys. Rev. A **84**, 021608(R) (2011).

Q 34.29 Tue 16:30 Poster.I+II

A Single Vortex in a Bose-Einstein Condensate — •Hamid Al-Jibbouri[1], Nikolas Zöller[1], and Axel Pelster[2] — [1]Institute for Theoretical Physics, Free University of Berlin, Germany — [2]Hanse-Wissenschaftskolleg, Delmenhorst, Germany

Within a variational approach we describe the physical properties of a Bose-Einstein condensate in a cylinder-symmetric harmonic trap with a single vortex in the center. At first we analyze the equilibrium configuration and determine the vortex size as well as the Thomas-Fermi radii. Then we calculate the critical rotation frequency for the emergence of the vortex and compare our findings with the literature. Finally, we investigate how the presence of the vortex changes the collective excitation frequencies. All results are obtained analytically in form of an asymptotic series in the limit of strong two-particle interactions.

Q 34.30 Tue 16:30 Poster.I+II

Geometric Resonances in BECs with Two- and Three-body Contact Interactions — •Hamid Al-Jibbouri[1], Ivana Vidanović[2], Antun Balaž[2], and Axel Pelster[3] — [1]Institute for Theoretical Physics, Free University of Berlin, Germany — [2]Scientific Computing Laboratory, Institute of Physics Belgrade, University of Belgrade, Serbia — [3]Hanse-Wissenschaftskolleg, Delmenhorst, Germany

We study geometric resonances of collective BEC modes, which arise due to the anisotropy of an axially-symmetric trapping potential [1]. To this end, we solve the time-dependent Gross-Pitaevskii equation at first analytically by using the perturbative expansion based on the Poincaré-Lindstedt analysis of a Gaussian variational ansatz [2]. By changing the anisotropy of the confining potential, we observe resonances and significant shifts in frequencies of collective modes, as well as mode coupling due to nonlinear effects. Numerically calculated results are found to be in good agreement with our analytical results. Finally, in addition to the previously studied case of two-body contact interactions, we also take into account three-body interactions [3] and study their effects on the properties of collective modes.

[1] F. Dalfovo, C. Minniti, and L. Pitaevskii, Phys. Rev. A. **56**, 4855 (1997).

[2] I. Vidanović, A. Balaž, H. Al-Jibbouri, and A. Pelster, Phys. Rev. A **84**, 013618 (2011).

[3] B. L. Tolra, K. M. O'Hara, J. H. Huckans, W. D. Phillips, S. L. Rolston, and J. V. Porto, Phys. Rev. Lett. **92**, 190401 (2004).

Q 34.31 Tue 16:30 Poster.I+II

Collision of two-dimensional anisotropic solitons — •Damir Zajec, Patrick Köberle, and Günter Wunner — 1. Institut für Theoretische Physik, Universität Stuttgart

Using the Gross-Pitaevskii equation, we perform grid calculations to determine the groundstates of anisotropic two-dimensional solitons in dipolar Bose-Einstein condensates, confined only perpendicular to the polarisation axis. The Split-Operator method is used to apply a general time evolution operator to an initial state, where time evolution is mainly described by a series of Fourier transforms. Since this numerical scheme is very demanding, the parallel computing architecture CUDA was used to implement the code. We study the coherent collision of two solitons, where initially the solitons are in the repelling side-by-side configuration and move towards each other with momentum k. We change the relative phases of the condensates, and introduce a total angular momentum by shifting one of the solitons along the polarisation axis.

Q 34.32 Tue 16:30 Poster.I+II

Exceptional points at bifurcations in dipolar Bose-Einstein condensates — •Robin Gutöhrlein, Jörg Main, and Günter Wunner — 1. Institut für Theoretische Physik, Universität Stuttgart

The nonlinearity in the extended Gross-Pitaevskii equation (GPE) describing dipolar Bose-Einstein condensates (BECs) can lead to degeneracies of the wave functions. We obtain the stationary states of the GPE by applying the time-dependent variational principle using an ansatz of coupled Gaussians. For cylindrical traps the linear stability of the ground state changes at a critical value of the scattering length.

A detailed analysis shows that the stability change is related to a pitchfork bifurcation. This bifurcation point exhibits the signatures of an exceptional point. Breaking the symmetry of the external trap the exceptional point splits up into three different exceptional points located in the complex scattering length plane. Encircling various combinations of the three branch points reveals the permutation behavior of a square root (EP2) and a cubic root exceptional point (EP3).

Q 34.33 Tue 16:30 Poster.I+II

Extended variational calculations of the stability and dynamics of Bose-Einstein condensates — •Manuel Kreibich, Jörg Main, and Günter Wunner — 1. Institut für Theoretische Physik, Universität Stuttgart, 70550 Stuttgart, Germany

The variational ansatz with coupled Gaussians is capable of predicting accurately the stationary solutions of the Gross-Pitaevskii equation. However, considering the dynamics, this ansatz can only describe monopolar, dipolar and quadrupolar modes. We present new extended variational approaches which are capable of describing, in principle, arbitrary angular momenta in spherically and cylindrically symmetric systems.

Using these approaches we calculate the stability of different systems and compare the results with those obtained by solving the Bogoliubov-de Gennes equations, which yield numerically exact solutions. Furthermore, we investigate the dynamics of Bose-Einstein condensates and observe the angular collapse of dipolar condensates.

Q 34.34 Tue 16:30 Poster.I+II

Bogoliubov Theory for Dipolar Bose Gas at Low Temperatures — •Tomasz Checinski[1] and Axel Pelster[2] — [1]Fakultät für Physik, Universität Bielefeld, Germany — [2]Hanse-Wissenschatskolleg, Delmenhorst, Germany

In this talk we extend the zero-temperature Bogoliubov theory for a homogeneous dipolar Bose gas of Ref. [1] to low temperatures. At first, we determine the validity region of the Bogoliubov theory in the plane spanned by the temperature and the gas parameter for varying dipolar interaction strength. To this end we demand that the combination of quantum and thermal depletion of the condensate remains small. Then we apply the anisotropic generalization of the Landau-Khalatnikov two-fluid model [2] in order to calculate the first and second sound velocity, respectively. The delicate interplay of the anisotropic dipolar interaction with both the quantum and the thermal fluctuations yields sound velocities with a characteristic angular dependence which should be detectable with modern Bragg spectroscopy.

[1] A.R.P. Lima and A. Pelster, Phys. Rev. A **84**, 041604(R) (2011); `arXiv:1111.0900`

[2] C. Wille and A. Pelster, to be published.

Q 34.35 Tue 16:30 Poster.I+II

Collisional interactions of metastable neon in different spin states — •Jan Schütz, Alexander Martin, Sanah Altenburg, and Gerhard Birkl — Institut für Angewandte Physik, Technische Universität Darmstadt, Schlossgartenstraße 7, 64289 Darmstadt

We investigate the interactions of laser cooled metastable neon (Ne*) in the $^3P_2$ state. The most remarkable feature of rare gas atoms in metastable states is their high internal energy which causes ionizing collisions, namely Penning and associative ionization. The resulting ions can be detected with high efficiency and accurate time resolution using electron multipliers. This serves as a direct probe for ionizing collisions and provides a close insight into the collision processes (see [1]) which cannot be studied in most other laser cooled atom samples.

As for He*, ionizing collisions in Ne* can be suppressed by preparing the atoms in spin-stretched states. The amount of suppression, however, depends crucially on the details of the interaction potentials and is limited due to the anisotropy of the interaction. In order to gain a deeper understanding of the collision process and to improve theoretical models, we measure rate coefficients of ionizing collisions for Ne* in individual $^3P_2$ Zeeman sublevels and mixtures of these states. We prepare the desired states using radio frequency pulses and several optical pumping schemes.

[1] W. Vassen, C. Cohen-Tannoudji, M. Leduc, D. Boiron, C.I. Westbrook, A. Truscott, K. Baldwin, G. Birkl, P. Cancio, M. Trippenbach, '*Cold and trapped metastable noble gases*', Rev. Mod. Phys. (in print), arXiv:1110.1361 (2011).

Q 34.36 Tue 16:30 Poster.I+II

Nonlinear Interaction Between Light Pulses Mediated by Four-Wave Mixing of Matter Waves — •Simon Baur, Stefan Riedl, Christoph Vo, Matthias Lettner, Gerhard Rempe, and Stephan Dürr — Max-Planck-Institute of Quantum Optics, Hans-Kopfermann-Str. 1, 85748 Garching

Coherent nonlinear interaction of weak light pulses is an important goal with various applications in quantum information processing and quantum metrology. Here we experimentally demonstrate a scheme where two weak light pulses propagating in two different momentum modes are stored as matter waves in a BEC of ^{87}Rb atoms using a Raman process. Due to atomic four-wave mixing of matter waves, an initially empty atomic momentum mode is populated. Finally all matter waves are converted back into light pulses. In this process, the new matter wave mode creates population in a light mode that was originally empty. In addition, we observe high contrast interference fringes in the read-out light as a function of the duration of the four-wave mixing. This shows that all involved processes, including the four-wave-mixing, are phase coherent. A novel conceptual aspect of our work is that it avoids the inherent need for high intensities in nonlinear optics by temporarily converting light into matter waves and making use of strong atom-atom interactions.

Q 34.37 Tue 16:30 Poster.I+II

Functional Renormalization Group Approach to the BCS-BEC Crossover — •Carlo Krimphoff and Lorenz Bartosch — Institut für Theoretische Physik, Goethe-Universität Frankfurt

The BCS-BEC crossover in two-component Fermi gases with short-range attraction has been, up to now, a subject of great interest. Besides recent experimental progress, a wide variety of methods has been used to address this problem theoretically, ranging from qualitative mean field approaches to quantum Monte Carlo simulations and various non-perturbative many-body methods.

In this work, we investigate the BCS-BEC crossover in three dimensions by means of a functional renormalization group approach with bosonization in the particle-particle channel. Going beyond previous approximation schemes by keeping the full momentum and frequency structure of the bosonic propagator, we calculate the effect of order parameter fluctuations on the chemical potential and the order parameter of the system and compare it to documented data from previous calculations.

Q 34.38 Tue 16:30 Poster.I+II

Interaction and Trapping Effects on 2D Topological Insulators in Optical Lattices — •Michael Buchhold[1], Daniel Cocks[1], Peter P. Orth[2], Stephan Rachel[3], Karyn Le Hur[4,3], and Walter Hofstetter[1] — [1]Institut für Theoretische Physik, Johann Wolfgang Goethe-Universität Frankfurt — [2]Institut für Theorie der Kondensierten Materie, Karlsruher Institut für Technologie — [3]Department of Physics, Yale University, New Haven — [4]Center for Theoretical Physics, École Polytechnique, Palaiseau

We investigate effects of interaction, disorder and trapping of a 2D system that exhibits topologically insulating phases in an optical square lattice using both real-space dynamical mean-field theory (R-DMFT) and analytical techniques. The tunability of this system allows for a large degree of freedom, and by adjusting the size of the magnetic unit cell, along with the strength of a spin-orbit coupling that does not preserve the S_z spin component and a staggered super-lattice potential, topologically non-trivial regions have been identified. Using R-DMFT, we determine the interacting phase diagram as a function of Hubbard U . We observe interaction driven transitions between the topological and normal insulating phase, as well as dependence of transitions to magnetically ordered phases on the flux parameter. We also analyze trapping effects that are relevant to experimental conditions and identify ideal trapping potentials that preserve the topological phases. This system is realizable (Goldman et al. PRL 105, 255302, 2010) as an effective Hamiltonian by generating a synthetic non-Abelian gauge field on the surface of an atom chip.

Q 34.39 Tue 16:30 Poster.I+II

Calaculation of the boune trajectory and macroscopic quantum tunneling rates of BEC with attractive 1/r-interaction — •Pascal Wieland, Kai Marquardt, Jörg Main, and Günter Wunner — 1. Institut für Theoretische Physik, Universität Stuttgart

Monopolar Bose-Einstein condensates with attractive 1/r-interaction, described by the Gross-Pitaevskii equation can decay due to macroscopic quantum tunneling. The tunneling rate depends on the Euclidean action of the bounce trajectory. To calculate the trajectory we use a time-dependent variational principle with an multi-gaussian ansatz. In addition numerical exact simulations are performed on space-time lattices, using a Split-Operator methode. The results for both approaches are compared.

Q 34.40 Tue 16:30 Poster.I+II

Rydberg-dressed Bose-Einstein condensates — •Nils Henkel[1], Fabian Maucher[1], Fabio Cinti[1], Rejish Nath[4], Mark Saffmann[2], Wieslaw Krolikowski[3], Stefan Skupin[1,5], and Thomas Pohl[1] — [1]Max Planck Institute for the Physics of Complex Systems, Dresden — [2]University of Wisconsin, Madison — [3]Australian National University, Canberra — [4]Institute for Quantum Optics and Quantum Information, Innsbruck — [5]Friedrich Schiller University, Jena

We study Bose-Einstein condensates where atoms are far off-resonantly coupled to highly excited Rydberg states with strong van-der-Waals interactions. This Rydberg dressing leads to effective soft-core interactions with striking consequences: in the case of attractive Rydberg states, they allow for the preparation of three-dimensional self-trapped solitons; the matter-wave analogue of so-called light-bullets. For repulsive Rydberg states, the interaction gives rise to a transition from a superfluid to a supersolid state. Both effects are shown to occur at experimentally accessible parameters.

Q 34.41 Tue 16:30 Poster.I+II

Collective scattering into the mode of an optical cavity — Simone Bux[1], •Hannah Tomczyk[1], Dag Schmidt[1], Philippe Courteille[2], and Claus Zimmermann[1] — [1]Physikalisches Institut, Universität Tübingen — [2]Instituto de Física de Sao Carlos, Universidade de Sao Paulo, Brasilien

Since many years, it is proven that optical or microwave resonators influence the spontaneous emission of atomic samples by changing the mode in which the atoms can emit light. We use this effect to change the momentum distribution of a Bose-Einstein condensate (BEC) in a controlled manner. In our experiment, a BEC is placed in the mode of an optical cavity. Shining a pump laser beam from the side on the BEC leads to scattering into the cavity mode and to the occupation of higher momentum states. Due to the narrow cavity line, the population can be controlled by the pump laser detuning [1]. A further goal is the realization of the subradiant state predicted in [2]. Once the system reaches this state, further scattering is suppressed and the population stays constant. Our experimental setup provides the necessary features. It would be one of the first evidences for subadiance with a large atom number.

[1] S. Bux, Ch. Gnahm, R. A. W. Maier, C. Zimmermann and Ph. W. Courteille, Phys. Rev. Lett. 106, 203601 (2011).

[2] M. M. Cola, D. Bigerni and N. Piovella, Phys. Rev. A 79, 053622 (2009).

Q 34.42 Tue 16:30 Poster.I+II

Cavity cooling of an atomic array — •Oxana Mishina and Giovanna Morigi — Theoretische Physik, Universität des Saarlandes, D-66041 Saarbrücken, Germany

In this work we discuss a ground state cooling of the motion of a large number of atoms as an important step on the way to control a many body system. The atoms form an array along the axis of a standing-wave optical resonators, and are confined by an optical lattice, due to an external classical field, whose periodicity may not be commensurate with the one of the cavity mode. The atoms are localized at the minima of the potential wells, and hopping and tunneling effects are neglected. In our model the cavity is pumped and the setup is similar to the one realised experimentally in [1]. Assuming the Lamb-Dicke regime, a set of equations is derived that describe the cooling dynamics of the atomic array. In particular, we identify the conditions under which only few collective modes of atomic motion are cooled, while the others are decoupled from radiation. Such a many body system with different interaction regimes can be a suitable resource for quantum technologies like quantum communications and computing.

[1] Optomechanical Cavity Cooling of an Atomic Ensemble M.H. Schleier-Smith, I.D. Leroux, H. Zhang, M.A. Van Camp, and V. Vuletić Phys. Rev. Lett. 107, 143005 (2011)

Q 34.43 Tue 16:30 Poster.I+II

Optical trapping of neutral mercury — •Holger John, Patrick Villwock, and Thomas Walther — Technische Universität Darmstadt, Institut für Angewandte Physik, Laser- und Quantenoptik, Schlossgartenstraße 7, 64289 Darmstadt

Laser-cooled mercury constitutes an interesting starting point for various experiment inparticular in light of the existence of bosonic and fermionic isotopes in relatively high natural abundance. On the one hand the fermionic isotopes could be used to develop a new time-standard based on a lattice optical clock employing the $^1S_0$ - $^3P_0$ transition at 265,6 nm. Another interesting venue is the formation of ultra cold Hg-dimers employing photo-association and achieving vibrational cooling by employing a special scheme.

A Yb:disc laser at 1014.8 nm is used for the trapping laser which is frequency-doubled twice to deliver up to 280 mW at 253.7 nm for the repump-free cooling process. For the photo-association process a fiber amplified and frequency quadrupled ECDL at 1016.4 nm is being setup which results in a large tuning range in the UV.

Due to the required power in the UV a power of about 5 W is needed in the fundamental. Since a linewidth of less than 1,27 MHz given by the cooling transition some care must be taken. We have successfully trapped the bosonic ^{202}Hg as well as the fermionic ^{199}Hg isotopes and have performed first temperature measurement. Currently, we are focussing on improving the reliability of the cooling and also of the photo-association-spectroscopy laser system. We will report on the status of the experiments.

Q 34.44 Tue 16:30 Poster.I+II

Interplay of cavity and EIT-cooling with neutral atoms in an optical resonator — •Sebastian Manz, Wolfgang Alt, Tobias Kampschulte, René Reimann, Seokchan Yoon, and Dieter Meschede — Institutfür Angewandte Physik der Universität Bonn, Wegelerstr. 8,53115 Bonn

The motional properties of single atoms inside an optical resonator can be changed significantly by the simultaneous interaction with a near-resonant control light field and a weak probing field coupled to the resonator. Following our findings in the case of electromagnetically induced transparency (EIT) with a single neutral atom [1] we investigate the roles of EIT cooling and cavity cooling within our system. We identify cooling and heating regions associated with the EIT-dark state or the atom-cavity dressed states [2]. By this the dressed states of the system and their dependency on the single- and two-photon-detunings can be investigated experimentally.

Further we show a qualitative difference in the cooling dynamics between one and two atoms coupled to the optical resonator.

[1] T. Kampschulte *et al.*, Phys. Rev. Lett. **105**, 153603 (2010)
[2] M. Bienert *et al.*, arXiv, 1109.1666v1 (2011)

Q 34.45 Tue 16:30 Poster.I+II

Towards Ultracold Mixtures on an Atom Chip — •Matthew Jones, Asaf Paris Mandoki, Sonali Warriar, Peter Krüger, and Lucia Hackermüller — University of Nottingham, UK

Ultracold mixtures hold the promise of understanding new phases of matter and collisions at very low energies. By combining the capabilities of the atom chip with optical dipole trapping, it will be possible to trap these mixtures in low dimensions and tune their scattering lengths via Feshbach resonances. In this way it will also be possible to realise experiments with additional magnetic potentials, position dependent interactions or impurity dynamics. Here we present the current status of our experiment. We detail the cooling schemes for both atom species and include the recent development of implementing an optical dipole trap. We discuss ideas for future measurements with separately addressable Bose-Fermi mixtures in optical dipole traps, such as transport and impurity studies in low dimensions, close to a chip surface.

Q 34.46 Tue 16:30 Poster.I+II

Using a single-atom tip electron source for ground state guiding of electrons — •Jakob Hammer, Johannes Hoffrogge, and Peter Hommelhoff — Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Straße 1, 85748 Garching bei München

A single-atom tip (SAT) consists of an atomically stacked pyramid on the apex of a sharp metal tip. Electron field emission from a SAT exclusively originates from the topmost atom of the pyramid. Therefore SATs are exceptionally bright and fully coherent point sources of electrons [1]. We report on ongoing experiments to use the SAT as a source to inject electrons into a miniaturized planar ac-quadrupole guide. Here low energy electrons are confined transversally in a tight 2D harmonic microwave potential [2]. By matching the spatial and momentum wavefunction of an incident electron with the ground state of the harmonic guiding potential, direct injection into the ground state should be feasible. Efficient ground state guiding requires a spot size of ~ 100 nm and an angular spread of ~ 1 mrad of the incoming electron wavefunction. In order to collimate the electron wavepacket transversally right after emission we are fabricating a sub-micron electrostatic lens. Miniaturization of the lens dimensions significantly reduces the lens aberrations while maintaining its focusing strength. We present the current status of the experiment as well as numerical simulations on quantum mechanical electron wavefunction propagation, revealing the efficacy of focusing close to the Heisenberg uncertainty limit.

[1] C.-C. Chang, et al., Nanotechnology 20, 115401 (2009).
[2] J. Hoffrogge, et al., Phys. Rev. Lett. 106, 193001 (2011).

Q 34.47 Tue 16:30 Poster.I+II

New nanofiber based trapping schemes and their applications — •Daniel Reitz, Bernhard Albrecht, Rudolf Mitsch, Philipp Schneeweiss, and Arno Rauschenbeutel — VCQ, TU Wien – Atominstitut, Stadionallee 2, 1020 Wien, Austria

Optical nanofibers can be used for trapping and optically interfacing cold neutral atoms in the evanescent field surrounding the fiber. For this purpose, a red-detuned trapping field is sent through the nanofiber and creates an attractive light-induced potential. To avoid collisions with the fiber surface, an additional, repulsive force is required. In our recently demonstrated trapping scheme, we use a blue-detuned fiber-guided field for this purpose. Here, we discuss the alternative of employing the centrifugal force instead. We show that a stable trap can be obtained with a 500-nm diameter nanofiber when assuming that the atoms possess $600\hbar$ of angular momentum with respect to the fiber axis. We propose to load the trap by first loading the atoms into a two-color trap, followed by an adiabatic transformation of the potentials. Interestingly, the wave-packet dynamics of the atoms in the angular momentum trap should yield a direct experimental proof of the quantization of the angular momentum of the atomic motion around the fiber. In addition to this angular momentum trap, we propose to trap atoms in a double-helix potential. Contrary to helical potentials realized with freely propagating light fields, the double-helix parameters can be locally set by a varying fiber waist diameter.

We gratefully acknowledge financial support by the Volkswagen Foundation and by the ESF.

Q 34.48 Tue 16:30 Poster.I+II

State preparation of cold cesium atoms in a nanofiber-based two-color dipole trap — •Rudolf Mitsch, Daniel Reitz, Philipp Schneeweiss, and Arno Rauschenbeutel — VCQ, TU Wien – Atominstitut, Stadionallee 2, A-1020 Wien

We have recently demonstrated a new experimental platform for trapping and optically interfacing laser-cooled cesium atoms. The scheme uses a two-color evanescent field surrounding an optical nanofiber to localize the atoms in a one-dimensional optical lattice 200 nm above the nanofiber surface [1, 2]. In order to use this fiber-coupled ensemble of trapped atoms for applications in the context of quantum communication and quantum information processing, an initialization of the atoms in a well defined quantum state has to be realized. In free-beam dipole traps, such a state preparation is usually achieved by means of optical pumping. However, the nanofiber guided fields exhibit a complex polarization pattern which hampers the implementation of standard optical pumping schemes based on, e.g., the interaction of the atoms with circularly polarized light. Here, we show that optical pumping of the atoms using fiber guided light fields is possible in spite of this fact.

Financial support by the Volkswagen Foundation, the ESF and the FWF (CoQuS graduate school) is gratefully acknowledged.

[1] E. Vetsch *et al.*, Phys. Rev. Lett. **104**, 203603 (2010).
[2] S. T. Dawkins *et al.*, Phys. Rev. Lett. **107**, 243601 (2011).

Q 34.49 Tue 16:30 Poster.I+II

a K-Rb setup for probing fermions in optical lattices — •Lucia Duca[1], Tracy Li[1,2], Monika Schleier-Ssmith[1,2], Martin Boll[2], Martin Reitter[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

In recent years there has been a growing interest in studying the Fermi-Hubbard model using ultracold fermions in optical lattices. Whereas previous experiments have primarily investigated the 3D Fermi-Hubbard model, little is known experimentally about phenomena in single 2D and coupled 2D Fermi-Hubbard systems.

Here we present a double species apparatus for studying Fermions in 2D Hubbard systems. In the experiment, the ^{40}K and ^{87}Rb atoms are laser-cooled using a combination of 2D+ and 3D magneto-optical traps (MOTs). The design for a 2D+MOT is presented, together with the experimental results obtained after optimization of the combined 2D+ and 3D MOTs. In particular, we jointly optimize the K and Rb atom numbers by using a dark spot MOT and by carefully choosing the temperature of the 2D MOT chamber, in order to minimize collisional losses. After the MOTs, the mixture is magnetically transported into a glass cell, where sympathetic and evaporative cooling to quantum degeneracy will occur. Finally, the atoms are loaded into the lattice.

We present the current status of this experimental setup, focusing on our new vacuum setup, magnetic transport design and the 2D lattice configuration.

Q 34.50 Tue 16:30 Poster.I+II

Enhanced loading for ultracold Calcium ensembles — •Max Kahmann, Sebastian Kraft, Oliver Appel, Dennis Le Plat, and Uwe Sterr — Physikalisch-Technische Bundesanstalt (PTB), Bundesallee 100, 38116 Braunschweig

For producing quantum degenerate ^{40}Ca we use a two stage magneto-optical trap (MOT) and subsequent forced evaporative cooling in an optical dipole trap. The first "blue" MOT on the transition $^1\mathrm{S}_0$ – $^1\mathrm{P}_1$ is used to capture atoms efficiently from a beam generated by a Zeeman-slower and to precool the atoms to temperatures in the order of a few mK. The second "red" MOT on the transition $^1\mathrm{S}_0$ – $^3\mathrm{P}_1$ cools the atoms further to typically 15 μK and ensures good transfer to the dipole trap.

A limiting factor both in atom number and for a fast repetition rate is the transfer of atoms from the density limited "blue" to the "red" MOT. To avoid this limitation we remove the repumper during the "blue" MOT and thus let the atoms decay to the metastable $^3\mathrm{P}_2$ state. This state is trapped within the magnetic quadrupole field of the MOT. The atoms can then at the end of the MOT stage be repumped to the ground state via the $^3\mathrm{D}_2$ and the $^3\mathrm{P}_1$ states with a diode laser at 446 nm. To provide long and short term stability we use a reference cavity made from ultra low expansion (ULE) glass placed in a vacuum chamber with an additional internal heat shield. The compact design of this system allows for an simple and robust stabilization of the laser.

This loading scheme will enable us to work with less abundant isotopes as the fermionic ^{43}Ca.

Q 34.51 Tue 16:30 Poster.I+II

Cavity cooling below the recoil limit — •Hans Kessler, Matthias Wolke, Jens Klinder, and Andreas Hemmerich — Institut für Laserphysik, Universität Hamburg

We experimentally explore a new regime of atom-cavity interaction, characterised by strong dispersive coupling and a small cavity linewidth permitting energy selectivity on the order of the recoil energy. This permits us to demonstrate cooling of an ensemble of ultra cold Rubidium below the recoil limit.

Q 34.52 Tue 16:30 Poster.I+II

Atomic scattering of metastable neon atoms — •Christian Cop and Reinhold Walser — Institute for Applied Physics, TU Darmstadt, Germany

Currently, many experiments are directed towards Bose-Einstein-Condensations of novel elements besides the alkalies: noble gases [1], rare-earth-gases and composite molecules. In the group of G. Birkl at the University of Darmstadt, the prospects for cooling metastable neon atoms (Ne*) to degeneracy are investigated experimentally [2]. Already the condensation of hydrogen (H) as well as metastable helium (He*) were affected by Penning ionization. Therefore it is also of crucial importance to investigate the collision properties of Ne*-atoms and asses the ratio of good to bad collisions. We have developed a numerical code for multichannel scattering and present recent results.

[1] W. Vassen, C. Cohen-Tannoudji, M. Leduc, D. Boiron, C. I. Westbrook, A. Truscott, K. Baldwin, G. Birkl, P. Cancio, M. Trippenbach, arXiv:1110.1361v1, (To be published in Rev. Mod. Phys.)
[2] P. Spoden, M. Zinner, N. Herschbach, W. van Drunen, W. Ertmer, G. Birkl, Phys. Rev. Lett. **94**, 223201 (2005)

Q 34.53 Tue 16:30 Poster.I+II

2D/3D-MOT System for the Production of Quantum-Degenerate Gases of Ytterbium — •Sören Dörscher, Alexander Thobe, Bastian Hundt, Christoph Becker, and Klaus Sengstock — Institut für Laserphysik, Universität Hamburg, 22761 Hamburg, Germany

Quantum gases of two-electron atoms are an exciting new branch within the field of ultracold atoms. Three different elements (Yb, Ca and Sr) and various isotopes have been cooled to degeneracy so far. Their complex level structure gives rise to a number of unique features such as long-lived electronically excited states interconnected by ultranarrow optical transitions and a near-perfect decoupling of the total spin from the electronic state and thus collisional processes.

Here, we report on a new experimental apparatus for the generation of ultracold quantum gases of Ytterbium atoms. With this setup we realize for the first time a two-dimensional magneto-optical trap (MOT) as a source of Ytterbium atoms, which we load directly into a three-dimensional MOT on the narrow $^1S_0 \to {}^3P_1$ intercombination transition. This loading scheme allows for a very compact apparatus that provides optimal, versatile optical access to the system.

Q 34.54 Tue 16:30 Poster.I+II

Using ytterbium to study many body physics in ultra-cold quantum gases — •Christian Hofrichter, Francesco Scazza, Pieter de Groot, Philip Ketterer, Immanuel Bloch, and Simon Fölling — MPI für Quantenoptik, Hans-Kopfermann-Straße 1, 85748 Garching and Ludwig-Maximilians-Universität, Schellingstraße 4, 80799 München, Germany

Ultracold atoms in optical lattices have already been demonstrated to be excellent prototype systems for condensed matter physics simulation and quantum information processing. Well-known Hamiltonians that play an important role in condensed matter systems like the Bose-Hubbard or Fermi-Hubbard-Hamiltonian can be studied on the microscopic level.

Alkaline-earth-type atoms with their bosonic and fermionic isotopes have some attractive properties that make them suitable for accessing new regimes of many body physics. They possess a long-lived excited state which can be used for example to implement a state-dependent lattice, enabling the realization of more complex classes of Hamiltonians. In addition the high nuclear spin of some of the fermionic isotopes, which at the same time is highly decoupled from the electronic states, gives rise to an enlarged SU(N) symmetry of the Hamiltonian. Theory predicts new ground state phases of magnetic ordering at sufficiently low temperatures for such systems with high SU(N) symmetry.

We will present our new setup designed for cooling ytterbium to degeneracy for quantum simulation experiments in state-dependent optical lattice potentials.

Q 34.55 Tue 16:30 Poster.I+II

Towards submicron trapping of ultra cold ensembles in cryogenic environments — •Christian Koller[1,2], Lucia Hackermüller[2], Samanta Piano[2], Mark Fromhold[2], and Peter Krüger[2] — [1]Vienna Center for Quantum Science and Technology, Atominstitut, TU Wien, Vienna, Austria — [2]Midlands Ultracold Atom Research Centre, School of Physics and Astronomy, University of Nottingham, UK

In recent times more and more theoretical and experimental proposals were made to combine ultra cold atoms with solid state systems, be it superconductors, semiconductors or nano structures. One of the crucial points in these projects is the ability to move an ensemble of ultra cold atoms ultra close to the surface one is interested in. This sub-micron trapping will allow the study of effects novel magnetic materials and semi conductor spin systems using Bose Einstein Condensate Microscopy or open the route for hybrid quantum systems. We will present here our experimental scheme to reach sub micron trapping on Atom chips using thin membrane chips to counter Casimir Polder Effects and traps utilizing 2D electron gases. The feasibility of the cryogenic atom chips needed will be investigated and reacted to existing experiments.

Q 34.56 Tue 16:30 Poster.I+II

Effects of geometry, size and dimensionality on the dynamics of correlated Rydberg gases — •Martin Gärttner[1,2], Thomas Gasenzer[2], and Jörg Evers[1] — [1]Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, D-69117 Heidelberg — [2]Institut für Theoretische Physik, Ruprecht-Karls-Universität Heidelberg, Philosophenweg 16, D-69120 Heidelberg

We study the coherent dynamics of a finite laser-driven cloud of ultracold Rydberg atoms by calculating the time evolution from the full many body Hamiltonian. Using the frozen gas approximation and treating the atoms as effective two level systems, we are mainly interested in the spatially resolved properties of the gas in its thermalized state. The time evolution of various observables such as the appearance of correlations are investigated. For resonant excitation the pair correlation function quickly builds up a sequence of maxima indicating the emergence of long range order. For non-zero detuning these long range correlations get even more pronounced due to resonant coupling to higher excited states [2]. We find that the Rydberg excitation in our calculation deviates from the algebraic scaling laws predicted in

[1]. This and many other features we observe can be attributed to the finite size of the Rydberg cloud we consider. Finally, we investigate the effects of inhomogeneous density, system geometry and dimensionality on our observables.
[1] H. Weimer *et al.*, Phys. Rev. Lett. 101, 250601 (2008)
[2] T. Pohl *et al.*, Phys. Rev. Lett. 104, 043002 (2010)

Q 34.57 Tue 16:30 Poster.I+II

A rate equation based model with exact two-body correlations — •Kilian Heeg and Jörg Evers — Max-Planck-Institut für Kernphysik, Heidelberg, Germany

New methods to describe clouds of Rydberg atoms are developed and compared to existing rate equation [1] and mean-field calculations [2]. We are particularly interested in the modeling of higher order correlations, and evaluate the performance of the different models via advanced observables like the pair correlation function and the Mandel Q parameter. In particular, we present an enhanced version of the rate equation model [1] which takes into account exact two-body correlations.
[1] C. Ates *et al.*, Phys. Rev. A 83, 041802(R) (2011)
[2] D. Tong *et al.*, Phys. Rev. Lett. 93, 063001 (2004)

Q 34.58 Tue 16:30 Poster.I+II

Narrow Band Excitation of a Dense Rydberg Gas in an Optical Dipole Trap — •Henning Labuhn, Christoph Hofmann, Georg Günter, Hanna Schempp, Martin Robert-de-Saint-Vincent, Shannon Whitlock, and Matthias Weidemüller — Physikalisches Institut, Universität Heidelberg, Philosophenweg 12, 69120 Heidelberg

Neutral Atoms in highly-excited (Rydberg) states are extremely polarizable particles. This leads to quantum effects and interactions over macroscopic distances. Consequently, many-body systems of Rydberg atoms offer a unique opportunity to create and investigate strong correlations in ultra-cold atomic gases.

In this prospect, we prepare dense quantum degenerate atomic samples in an optical dipole trap. The geometry can be changed from 1D to 2D or 3D by using specific optical potentials. In particular, we present a compact and modular system for trapping the atoms in a shallow-angle 1D optical lattice. In addition, narrow band laser sources are used for probing the spectral features of interactions in electromagnetically-induced transparency (EIT)[1], and preparing correlated many-body Rydberg states. For this we aim to lock the laser to an ultra-stable optical resonator which is temperature and vibration isolated from its environment. First results on interaction effects in EIT configuration are presented. These studies will ultimately shed new light on self-ordering in complex many-body quantum systems [2].
[1] G. Günter et al., arXiv:1106.5443v1 (2011), to be published in PRL
[2] S. Sevinli et al., Phys. Rev. Lett. 107, 153001 (2011)

Q 34.59 Tue 16:30 Poster.I+II

Ultra-longe-range Rydberg molecules in crossed electric and magnetic fields — •Markus Kurz and Peter Schmelcher — Zentrum für Optische Quantentechnologien

We present the properties of ultra-long-range Rydberg molecules exposed to crossed electric and magnetic fields. We calculate the adiabatic potential surfaces via an exact diagonalization technique. These surfaces posses a rich topology depending on the degree of electronic excitation. Additionally, we analyze the binding energies and the vibrational motion in the energetically lowest surfaces.

Q 34.60 Tue 16:30 Poster.I+II

A Biprism-Interferometer for Ions and charged Molecules — •Andreas Pooch[1], Alexander Rembold[1], Georg Schütz[1], Franz Hasselbach[1], Ing-Shouh Hwang[2], and Alexander Stibor[1] — [1]Quanten-Ionen-Interferometrie, Physikalisches Institut, Universität Tübingen, Auf der Morgenstelle 15, 72076 Tübingen — [2]Institute of Physics, Academia Sinica, Taipei, Taiwan, R.O.C.

Important achievements have been accomplished within the last centuries in matter-wave interferometry for electrons, neutral atoms, neutrons and neutral molecules. However, until now the field lacks of experiments with ions and charged molecules. Even if a novel interferometer for ions combines the advantages of the other approaches: The high technical standard in the generation and precise control of electron beams can be used also on ions. The charge makes them applicable to novel fundamental experiments in connection with the magnetic and electrostatic Aharonov-Bohm effect. The inner structure of ions allows the manipulation of inner degrees of freedom such as laser excitation of ionic states or vibrational excitation in charged molecules.

Here we present the design and the current status in the construction of the first stable ion-interferometer. In our setup the charged matter-wave will be generated by a novel single-atom metal tip and separated by a fine charged biprism wire. The longitudinal coherence is adjusted by a Wien-filter and the interference pattern will be detected after quadrupole magnification by a delayline detector.

We also discuss future applications for ion-interferometers as highly sensitive sensors for rotation and acceleration.

Q 34.61 Tue 16:30 Poster.I+II

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 including vacuum, lasers, optics, and electronics. The LASUS project develops diode lasers, optical modules and electronics for such experiments, and specifically for the QUANTUS experiments in the drop tower in Bremen and on sounding rockets. In this poster we present the electronics that have been developed to operate an entire laser system for capturing and manipulating rubidium and potassium together with the electronics for the optical switching and frequency shifting, and that fits in a volume of only a few liters. We will pay special attention to the FPGA-based frequency controller which integrates the modulation and demodulation circuits for a spectroscopy lock as well as several frequency counters for offset locking together with the PID controllers in a single compact device. All parameters of the device are computer controlled enabling advanced features like automatic searching for an atomic transition or automatic recovery of errors. 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 34.62 Tue 16:30 Poster.I+II

Propagation of classical light through non-stationary but spatially homogeneous media — •Armen G. Hayrapetyan[1,2], Karen K. Grigoryan[3], Babken V. Khachatryan[3], Rubik G. Petrosyan[3], and Stephan Fritzsche[4,5] — [1]Physikalisches Institut, Universität Heidelberg, D-69120 Heidelberg, Germany — [2]Max-Planck-Institut für Kernphysik, Postfach 103980, D-69029 Heidelberg, Germany — [3]Yerevan State University, 1 Alex Manoogian Str., 0025 Yerevan, Armenia — [4]Department of Physics, P.O. Box 3000, Fin-90014 University of Oulu, Finland — [5]GSI Helmholtzzentrum für Schwerionenforschung, D-64291 Darmstadt, Germany

The propagation of light through a spatially homogeneous but nonstationary medium is explored within the framework of classical electrodynamics. For a non-absorbing medium, especially, a generalized wave equation is derived for the electric field in terms of the refractive index of the medium. A solution of this equation for finite transition period τ in terms of the hypergeometric function is determined for a phenomenologically realistic, sigmoidal change of the refractive index. Using this solution, it is shown that the energy of the light wave is not conserved, it either increases or decreases in dependence of the particular change of the refractive indexes. An interpretation of this wave phenomenon is given similar to the work by Feynman and Stueckelberg for the propagation of anti-particles. The reflection and transmission coefficients are analyzed especially for optical frequencies.

Q 34.63 Tue 16:30 Poster.I+II

An optical dipole trap as a source for atom interferometry — •Dennis Schlippert, Jonas Hartwig, Ulrich Velte, Daniel Tiarks, Sven Ganske, Olga Lysov, Wolfgang Ertmer, and Ernst Rasel — Institut für Quantenoptik, Leibniz Universität Hannover, Welfengarten 1, 30167 Hannover

We report on our work directed towards using an optical dipole trap (ODT) at a wavelength of 2 μm as a source for atom interferometry. Applications for single-species (^{87}Rb) and dual-species (^{87}Rb + ^{39}K) gravimetry are discussed. Loading the ODT from a single (dual) species 2D/3D-magneto-optical trap enables accurate initial position control and allows to precisely colocate two ensembles, when operated in dual-species mode. Additionally, use of evaporative and/or sympathetic cooling techniques is possible.
We present an analysis of an ODT source and show the benefits over

state-of-the-art optical molasses sources when dealing with systematic effects, e.g. non-negligible transversal atomic spread, the Coriolis phase and gravity gradient errors.

Q 34.64 Tue 16:30 Poster.I+II

CASI Gyroscope Experiment — •Sven Abend, Peter Berg, Gunnar Tackmann, Christian Schubert, Wolfgang Ertmer, and Ernst M. Rasel — Institut für Quantenoptik, Leibniz Universität Hannover

We report on the status of the cold atom gyroscope at Leibniz Universität Hannover which encloses areas as large as 19 mm^2 within a baseline of only 13.7 cm. This large enclosed interferometric area at a short baseline is a key feature to build a high resolution sensor while remaining compact and transportable. The sensor currently operates at a sensitivity of $5.3\cdot 10^{-7}$ rad/s/$\sqrt{\mathrm{Hz}}$. We discuss the stability of the interferometric contrast and phase. The targeted sensitivity is in the lower 10^{-8} rad/s regime. This work is supported by the DFG, QUEST, and IQS.

Q 34.65 Tue 16:30 Poster.I+II

MAIUS - a rocket-borne atom-optical experiment — •André Kubelka[1], Sven Herrmann[1], and the QUANTUS Team[1,2,3,4,5,6,7,8,9] — [1]ZARM, Universität Bremen — [2]Institut für Quantenoptik, LU Hannover — [3]Institut für Physik, HU Berlin — [4]Institut für Laserphysik, 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]DLR R-Y, Bremen

MAIUS will be an atom-optical experiment that will show the feasibility of experiments with ultra-cold quantum gases in microgravity in a sounding rocket. The MAIUS setup will be able to produce a sample of ultra-cold atoms on-board a sounding rocket of the type VSB-30 launched at Esrange, Sweden. It is designed to create a Bose-Einstein-Condensate of 10^5 ^{87}Rb-atoms in less than 5 s and observe its evolution over periods on the order of a few seconds. Additionally it will be possible to probe the properties of the sample using atom interferometric techniques. The laser fields and magnetic fields used for trapping and manipulating the atoms will be created by special hardware designed with the requirements of a rocket mission in robustness, miniaturization and power usage in mind. Special attention is thereby also spent on the appropriate magnetic shielding from varying magnetic fields during the rocket flight.

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 1135.

Q 34.66 Tue 16:30 Poster.I+II

Matter-wave interferometry with Bose-Einstein condensates within the scaling approximation — •Wolfgang Zeller[1], Stefan Arnold[1], Stephan Kleinert[1], Endre Kajari[1,2], Vincenzo Tamma[1], Albert Roura[1], Wolfgang P. Schleich[1], and the QUANTUS-TEAM[3,4,5,6,7,8,9,10] — [1]Institut für Quantenphysik, Universität Ulm — [2]Theoretische Physik, Universität des Saarlandes — [3]Institut für Quantenoptik, LU Hannover — [4]ZARM, Universität Bremen — [5]Institut für Physik, HU Berlin — [6]Institut für Laser-Physik, Universität Hamburg — [7]Institut für angewandte Physik, TU Darmstadt — [8]Midlands Ultracold Atom Research Centre, University of Birmingham, UK — [9]FBH, Berlin — [10]MPQ, Garching

The prospect of atom interferometers in space opens up an avenue for tests of the equivalence principle with unprecedented precision. In this context, Bose-Einstein condensates (BECs) represent a promising source for matter-wave interferometry. Building upon a generalization of the common scaling approach which has been successfully employed to describe the long-time evolution of a BEC in microgravity [1], we analyze the interference pattern by coherently superimposing different macroscopic wave functions. We apply this method to study the interference of BECs in several scenarios and compare our results to numerical simulations based on the Gross-Pitaevskii equation.

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

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

Q 34.67 Tue 16:30 Poster.I+II

Representation-free description of matter wave interferometry — •Stephan Kleinert[1], Wolfgang Zeller[1], Vincenzo Tamma[1], Albert Roura[1], Endre Kajari[2], Daniel M. Greenberger[3], Ernst M. Rasel[4], and Wolfgang P. Schleich[1] — [1]Institut für Quantenphysik, Universität Ulm, D-89081 Ulm, Germany — [2]Theoretische Physik, Universität des Saarlandes, D-66041 Saarbrücken, Germany — [3]City College of New York, NY 10031, USA — [4]Institut für Quantenoptik, Leibniz Universität Hannover, D-30167 Hannover, Germany

The recent controversy about the measurement of the gravitational redshift by means of atom interferometry [1] has gained a lot of attention. In this context, the interpretation of the individual contributions to the phase-shift is based on the Feynman path integral approach [2], which is naturally connected to the position representation. However, the separation into different contributions seems to be ill-founded because the interpretation changes when the phase-shift is evaluated in momentum representation [3]. For this reason, we pursue a representation-free description of matter wave interferometry that is solely based on operator algebra methods. We present a straightforward method to determine the phase-shift for arbitrary interferometer geometries taking into account the local gravitational acceleration, the gravity gradient and a rotation of the device.

[1] H. Müller, A. Peters, S. Chu, Nature **463**, 926 (2010).
[2] P. Storey, C. J. Cohen-Tannoudji, Phys. II France **4**, 1999 (1994).
[3] W. P. Schleich, D. M. Greenberger, E. M. Rasel, *in preparation*.

Q 34.68 Tue 16:30 Poster.I+II

Towards a dual species matter-wave interferometer in microgravity — •Tammo Sternke[1], Claus Lämmerzahl[1], Ernst M. Rasel[2], and the QUANTUS TEAM[1,2,3,4,5,6,7,8,9] — [1]ZARM - Universität Bremen — [2]Institut für Quantenoptik, LU Hannover — [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 — [8]FBH, Berlin — [9]DLR Institut für Raumfahrtsysteme, Bremen

Matter wave interferometers with chip-based atom lasers have proven their reliability in microgravity experiments as provided by the Bremen drop tower. The pioneering QUANTUS experiment has realized Bose-Einstein condensates with 10 000 ^{87}Rb Atoms and a subsequent unperturbed free evolution time of 1s in microgravity[1].

In this poster we present the upgrade of this experiment, QUANTUS II. It comprises a novel atom chip for interferometry with a quantum degenerate mixture of two species (^{87}Rb - ^{40}K) and enhanced performance in particle number for catapult flights doubling the available microgravity time to 9.4s. The longterm goal is a test of Einstein's weak equivalence principle with quantum objects.

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 1135.

[1] T. van Zoest et al., "Bose-Einstein condensation in microgravity", Science, vol 328, no. 5985, p. 1540, 2010

Q 34.69 Tue 16:30 Poster.I+II

Glass-ceramic based laser systems for atom optics in microgravity — •Hannes Duncker[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

Experimental atom optics under conditions of microgravity places stringent requirements on the deployed laser systems in terms of reliability, robustness, weight, volume and power consumption. We present new technologies which meet these demands in order to support ongoing experiments performed within the QUANTUS project at the drop tower facility in Bremen and make future sounding rocket missions feasible. For the latter, a compact glass-ceramic 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 is currently in its design phase. To this end, micro-optically integrated diode lasers covering the spectral range from 767 nm to 780 nm are currently being developed. Such a system paves the way for future tests of the universality of free fall using a dual species atom interferometer.

The LASUS 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 50WM0938.

Q 34.70 Tue 16:30 Poster.I+II

Mach-Zehnder type interferometry with Bose-Einstein condensates in microgravity — •Markus Krutzik[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, Garching — [7]Institut für angewandte Physik, TU Darmstadt — [8]Midlands Ultracold Atom Research Centre, University of Birmingham, UK — [9]FBH, Berlin

Inertial sensors based on interferometry with ultra cold matter waves are proven to be a very promising tool for fundamental physics missions in space, as for instance testing the Einstein equivalence principle. The successful observation of Bose-Einstein condensation in microgravity (van Zoest et al., Science 328 2010) was an important result towards realizing coherent sources for atom interferometry under extreme conditions. We have now implemented a matter wave interferometer based on the coherent manipulation of the BEC with stimulated Bragg diffraction as a splitting and recombination process. In recent drop campaigns we have analyzed long-time coherence properties of the macroscopically separated wave packets in a Mach-Zehnder configuration. In this poster we present our experimental apparatus in detail and summarize latest results.

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 50WM 1131-1137.

Q 34.71 Tue 16:30 Poster.I+II

Double-diffraction scheme for a Bragg matter-wave interferometer — Enno Giese[1], •Albert Roura[1], Ernst M. Rasel[2], and Wolfgang P. Schleich[1] — [1]Institut für Quantenphysik, Universität Ulm — [2]Institut für Quantenoptik, LU Hannover

Two pairs of counterpropagating laser beams have recently been employed to implement a double-diffraction scheme for atom interferometers based on two-photon stimulated Raman transitions [1]. This enables symmetric configurations which mitigate the effect of noise sources acting differently on atoms with different internal states as well as doubling the momentum transfer. Combined with the use of retroreflected beams it also helps reduce systematic effects due to wave-front distortions. On the other hand, Bragg diffraction has been shown to be a suitable and convenient technique for interferometry with Bose-Einstein condensates (BECs) [2]. Here we analyze the extension of symmetric configurations based on double diffraction to this case. In particular we study in detail the adiabatic elimination of the detuned excited state and the richer dynamics associated with the effective Hamiltonian for the resulting three-dimensional Hilbert space. This could have important applications to matter-wave interferometry with cold atoms in space.

[1] T. Lévêque et al., Phys. Rev. Lett. **103**, 080405 (2009).
[2] Y. Torii et al., Phys. Rev. A **61**, 041602(R) (2000).

Q 34.72 Tue 16:30 Poster.I+II

Advanced laser systems for atom interferometry in microgravity — •Markus Krutzik[1], Achim Peters[1] und the QUANTUS Team[1,2,3,4,5,6,7,8,9] — [1]Institut für Physik,HU Berlin — [2]Institut für Quantenoptik, LUHannover — [3]Institut für Laserphysik, UniHamburg — [4]ZARM, Uni Bremen — [5]Institut für Quantenphysik, Uni Ulm — [6]MPQ, Garching — [7]Institutfür angewandte Physik, TU Darmstadt — [8]MidlandsUltracold Atom Research Centre, University of Birmingham, UK — [9]FBH, Berlin

In various fields of fundamental physics and metrology, inertial sensors based on matter waves are continuously gaining importance. The sensitivity of matter wave interferometers is mainly limited by the free expansion time of the ultra-cold sample, their ultimate sensitivity can only be reached in space. In this poster we present advanced laser systems for high precision quantum gas experiments on different microgravity platforms like drop tower capsules, sounding rockets and satellites. Special challenges in the construction of the particular laser systems are posed by the challenging and tough environment, putting stringent requirements on the performance of laser sources. Diode-laser based systems have been developed, which successfully passed mechanical stability tests (50g) and vibration tests, that simulate mechanical loads of a sounding rocket launch (8 gRMS).

The QUANTUS and LASUS project are supported by the German Space Agency DLR with funds provided by the Federal Ministry of Economics and Technology (BMWi) under grant number DLR 50WM 1131-1137 and 0937-0940.

Q 34.73 Tue 16:30 Poster.I+II

Towards an optical Al^+ clock using quantum logic — •Sana Amairi, Jannes Wübbena, Olaf Mandel, and Piet Schmidt — QUEST Institute of Experimental Quantum Metrology Physikalisch-Technische Bundesanstalt (PTB) and Leibniz University of Hannover Bundesallee 100 D-38116 Braunschweig, Germany

We present the status of our transportable optical clock based on quantum logic interrogation of a single Aluminum ion. The design goals for the frequency standard are an inaccuracy of 10^{-17} or better and relative stability of 10^{-15} in one second. $^{27}Al^+$ has been chosen as the clock ion since it has a narrow ($8mHz$) clock transition at $267nm$ which exhibits no electric quadruple shift and a low sensitivity to black-body radiation. The $^{27}Al^+$ *clock ion* will be trapped together with a $^{40}Ca^+$ ion which will act as a *logic ion* and is used for sympathetic cooling and internal state detection of the clock ion with techniques developed for quantum information processing. We set up a linear trap with sapphire insulators and titanium electrodes to improve thermal management and minimal magnetic field distortions. The short term stability of the clock is provided by a $39.5cm$ long ultra-stable optical cavity. The long cavity is estimated to be thermal noise limited at an instability level of 4×10^{-17} at $1Hz$. Finite element simulations were used to reduce the sensitivity to vertical and horizontal acceleration to below the $10^{-12}/g$ level for alignment tolerances of up to $100\mu m$. For Clock comparison beyond a fractional uncertainty of 10^{-16} we plan to build a portable system that allows us to travel to other sites and perform frequency measurements.

Q 34.74 Tue 16:30 Poster.I+II

Microwave driven nanoscopic resolution of two neighbour single NV centres in diamond: Micro-(wave)-scopy — •Andreas Häussler[1], Luca Marseglia[1], Florian Striebel[1], Manfred Bürzele[1], Ressa Said[2], Pascal Heller[1], Philip Hemmer[3], Jörg Wrachtrup[4], and Fedor Jelezko[1] — [1]Institut für Quantenoptik, Universität Ulm, Germany — [2]Institut für Quanteninformationsverarbeitung, Universität Ulm, Germany — [3]Electrical and Computer Engineering, Texas A&M University, College Station, TX 77843, USA. — [4]3. Physikalisches Institut, Universität Stuttgart, Germany

The negatively charged Nitrogen Vacancy color center (NV) is a spin active defect in diamond with a long spin lifetime at room temperature. It is a three level system whose value of the spin of the ground state can be driven by applying a microwave field (2.88 GHz). We aim to resolve two different NV centres separated by a distance in nanoscopic regime. Instead of using advanced confocal microscopy methods we exploit Rabi oscillations of the spin of the NV centre which show a spatial dependence due to applied microwave fields. Therefore we fabricate a microwave circuit, directly placed onto the diamond, which will allow us to apply different high intensity microwave fields and gradients. Besides this, knowing the spatial behaviour of the microwave field is crucial. To this aim we perform simulations of the microwave circuit also characterising them. Finally the relation between the Rabi oscillations and the microwave field of two NV centres close to each other can be used in order to compute the distance between them, with a resolution below 50 nm.

Q 34.75 Tue 16:30 Poster.I+II

Towards High Precision Laser Spectroscopy and Ground-State Cooling of a Mixed Species Coulomb Crystal — •David-M. Meier[1], Jonas Keller[1], Karsten Pyka[1], Kristijan Kuhlmann[1], and Tanja E. Mehlstäubler[1,2] — [1]Quest-Institute, Physikalisch-Technische Bundesanstalt — [2]Department of Time & Frequency, Physikalisch-Technische Bundesanstalt, Braunschweig

The investigation of trapped ion Coulomb crystals is an active topic in the field of optical clocks, quantum sensors and quantum logic.

In our experiment we use $^{172}\mathrm{Yb}^+$ ions in laser cooled Coulomb crystals to sympathetically cool $^{115}\mathrm{In}^+$ to realize an optical frequency standard with indium ions as clock ions. We set up an ultra-stable laser at 411nm to perform ground-state cooling on the forbidden $^2S_{1/2}$ to $^2D_{5/2}$ quadrupole transition of $^{172}\mathrm{Yb}^+$. This laser will enable precise measurements of the crystal temperature and heating rates, the study of the mode structure and systematic shifts in such a clock.

We present the experimental set-up of our sub-Hz linewidth laser (fractional frequency instability 6×10^{-16}) at 822nm stabilized on a high-finesse ULE® cavity of 12cm length, which is frequency doubled with PPKTP in a bow-tie enhancement cavity. An output power of 24mW at 411nm out of 60mW IR was realized. Coulomb crystals with many ions display a complex mode-structure, which makes sideband-cooling and spectroscopy more difficult. We report on the calculations of radial and axial mode frequencies for a mixed ion species ($^{115}In^+/^{172}Yb^+$) crystal and discuss our scheme for ground-state cooling.

Q 34.76 Tue 16:30 Poster.I+II

Ultrastable laser system for a magnesium optical lattice clock — •Steffen Rühmann, Andre Pape, Temmo Wübbena, André Kulosa, Hrishikesh Kelkar, Dominika Fim, Klaus Zipfel, Wolfgang Ertmer, and Ernst M. Rasel — Institut für Quantenoptik, Leibniz Universität Hannover, Welfengarten 1, 30167 Hannover, Germany

Current optical clocks promise to exceed the current performance of microwave clocks. We currently upgrade our magnesium clock with an optical lattice. Ultracold magnesium atoms are captured in a magneto-optical trap and in near future in an optical lattice at the magic wavelength [1] for high precision spectroscopy of the ultranarrow $^1S_0 \rightarrow {}^3P_0$ clock transition.

The frequency measurement of this sub-Hz wide transition sets stringent requirements with respect to the clock laser. For this purpose we built two independent diode laser systems @ 914 nm which are stabilized to independent high finesse resonators. The resonators are housed horizontally in a vacuum chamber and are mounted such that influence of vibrations is effiently supressed. We use mirror substrates made of fused silica setting the thermal noise floor to 3×10^{-16}. We achieved a fractional instability of one cavity of 5×10^{-16} in 1 s which is comparable to the highest reported stabilities for cavity-stabilized lasers. We describe the current status and performance of our ultrastable laser systems.

[1] Takamoto et al., An optical lattice clock, *Nature* **435**, 321-324 (2005)

Q 34.77 Tue 16:30 Poster.I+II

Building a transportable optical lattice clock — •Stefan Vogt, Sebastian Häfner, Stephan Falke, Uwe Sterr, and Christian Lisdat — Physikalisch-Technische Bundesanstalt, Bundesallee 100, 38116 Braunschweig

Optical clocks are today's most stable frequency standards. Moreover, their precision has surpassed the limits of microwave clocks. Although frequency combs allow for comparison of the ratio of optical frequencies, few comparisons of optical clocks have been reported. This is mostly due to the lack of transportability of these rather bulky and fragile instruments that sometimes fill several rooms.

The comparison of optical frequency standards is needed for a possible re-definition of the second. Moreover, transportable optical clocks may serve as reference for experiments looking for variations of fundamental constants. Future satellite mission may investigate special relativity on a level set by the stability of an on-board clock, which leads to the challenge of putting an optical clock onto a space-craft.

We will present a design of an optical lattice clock working on a ultra-narrow transition of ^{87}Sr with a stability of $1 \cdot 10^{-15} s^{-1/2}$ and a relative accuracy of better than $5 \cdot 10^{-17}$. This is a modular system to be transported in a small trailer to a lab of our choice.

This work is supported by the Centre for Quantum Engineering and Space-Time Research (QUEST) and EU through the Space Optical Clocks (SOC2) project.

Q 34.78 Tue 16:30 Poster.I+II

Nanoscale sensing of a magnetic topology — •Alexander Gerstmayr[1], Christoph Müller[1], Fedor Jelezko[1], Marcus Liebmann[2], and Markus Morgenstern[2] — [1]Institut für Quantenoptik, Universität Ulm — [2]Physikalisches Institut IIb, RWTH Aachen

For years, the nitrogen-vacancy (NV) center in diamond has been in the spotlight for studies of electron spin coupling. Also the coupling to other near color centers in diamond was studied recently. We will explore single atom control techniques for sensing external spins and imaging them using scanning probe microscopy. External magnetic fields cause a frequency shift of the electron spin resonance of our NV-center, which is detectable by Optically Detected Magnetic Resonance (ODMR). One single NV-center located in a diamond tip is the main part of the future AtomicForce- and MagneticResonanceMicroscope (AFM/MRM). Due to the possibility of single-spin detection in NV-centers under ambient conditions, this combination of AFM and MRM is planned to work even at room temperature as well as low temperature (4 K). We will be able to locate singel spins on the nanoscale.

Q 34.79 Tue 16:30 Poster.I+II

Influence of Photon Number Statistics on the Relative Detection Efficiency Calibration of Single Photon Detectors — •Waldemar Schmunk, Silke Peters, Helmuth Hofer, Johannes Dühn, and Stefan Kück — Physikalisch-Technische Bundesanstalt, Bundesallee 100, D-38116 Braunschweig

The detection efficiency η_D of a silicon single photon avalanche detector (Si-SPAD) in Geiger operation mode is an important property in a wide field of applications. Here we present a method for relative detection efficiency calibration for fiber-coupled detectors. In this context we discuss specifically how the photon number statistics of the applied light source influences the determination of the detection efficiency. The results obtained using different light emitters in the calibration process, i.e. classical light emitters like thermal sources or lasers and non-classical sources, e.g. single photon emitters based on nitrogen vacancy (NV-) centers in diamond, are compared. Already for mean photon numbers of about 0.1 the differences in the η_D determination are in the percent range. Furthermore, we determined the photon number distribution of several NV-center-based emitters exhibiting different values of the second order intensity correlation function at zero time delay $g^{(2)}(0)$. The results obtained with a photon number resolving transition edge sensor (TES) and with the On/Off detection technique are in good agreement with the measured $g^{(2)}(0)$-value from a Hanbury Brown-Twiss interferometer.

Q 34.80 Tue 16:30 Poster.I+II

A resonator-based optical lattice setup for an Yb clock — •Tobias Franzen, Charbel Abou Jaoudeh, Gregor Mura, and Axel Görlitz — Institut für Experimentalphysik, HHU Düsseldorf, Universitätsstr. 1, 40225 Düsseldorf

Optical lattice clocks based on rare earths are expected to eventually reach an inaccuracy at a level of 10^{-18}. While promising results have already been obtained on several stationary setups using Sr and Yb, transportable clocks are desirable for both performance evaluation and applications. For the realization of a transportable Yb clock, we are developing a compact, diode laser based atom source.

A key component of our setup is a resonator-based optical lattice at the magic wavelength for Yb. Resonant enhancement of the trapping light in an intravacuum optical cavity allows us to create sufficiently deep traps (several 100 μK) with a high volume (several 100 μm diameter) using a standard diode laser system ($\sim$ 500 mW). A large trap volume enables the loading of a substantial portion of the MOT into the lattice and is thus beneficial for future clock performance due to a larger available atom number.

We present a versatile setup for the evaluation of different large volume lattice geometries in our clock apparatus, demonstrate the efficient transfer from the postcooling MOT into a one-dimensional optical lattice at the magic wavelength and characterize the system with regard to clock operation.

Q 34.81 Tue 16:30 Poster.I+II

Absorptionsmessungen durch photothermische Selbstphasenmodulation — •Christoph Krüger, Jessica Steinlechner und Roman Schnabel — Institut für Gravitationsphysik, Leibniz Universität Hannover und Max-Planck-Institut für Gravitationsphysik (Albert-Einstein-Institut), Callinstr. 38, 30167 Hannover, Germany

Für viele optische Anwendungen sind geringe Absorptionen oder deren genaue Bestimmung von Interesse. Uns ist es gelungen ein Messverfahren zu entwickeln, welches die durch photothermische Selbstphasenmodulation hervorgerufene Verformung von Airy-Peaks eines optischen Resonators nutzt. Auch mit geringen Laserleistungen kann so die Absorption von Substraten innerhalb eines Resonators, aber auch die der Spiegelbeschichtungen, bestimmt werden. Erste Messungen konnten aus der Literatur bekannte Absorptionskoeffizienten wiedergeben.

Auf diese Weise konnten wir mit Hilfe eines Ringresonators die Absorption von hochreflektierenden Ta_2O_5/SiO_2 Spiegelbeschichtungen bestimmen. Unser Verfahren ermöglicht es Substrate zu vermessen, deren Absorptionskoeffizienten sich um mehrere Größenordnungen unterscheiden. SiN-Membranen verschiedener Dicken, wie sie auch in optomechanischen Experimenten verwendet werden, konnten bei den Laserwellenlängen 1064nm und 1550nm in Resonatoren mit einer Finnesse von 500 bzw. 1000 untersucht werden und lieferten je nach Wellenlänge und Membrandicke Ergebnisse zwischen 10ppm und 1000ppm pro Durchgang.

Q 34.82 Tue 16:30 Poster.I+II

Blackbody radiation shift correction of an optical lattice clock

from dc Stark shift measurements — •Thomas Middelmann, Stephan Falke, Uwe Sterr, and Christian Lisdat — Physikalisch-Technische Bundesanstalt, Bundesallee 100, 38116 Braunschweig

Good properties for laser cooling and laser trapping often come at the price of a significant sensitivity to blackbody radiation of room temperature environments. For example, optical lattice clocks based on an ultra-narrow transition in ^{87}Sr are nowadays limited in their uncertainty by the uncertainty of the frequency shift induced by the ambient blackbody radiation. As experiments with Cs microwave clocks have shown, measuring the shift induced by a dc electric field may allow to correct the blackbody radiation shift with high accuracy. This is true for our ^{87}Sr clock as well because both clock states are coupled to other states only by transitions that are energetically significantly higher than the peak of the blackbody radiation. Therefore, the blackbody radiation induced shift can be described by the dc Stark shift of its rms electric field to a good approximation.

We apply a dc electric field to the atoms via a specifically designed precision capacitor: Glass plates with a semi-transparent gold layer are optically contacted to gauge blocks. Their separation has been measured interferometrically. With our measurement we will improve the coefficient of the blackbody radiation shift such that its uncertainty only attributes to less than $2 \cdot 10^{-17}$ to the overall clock uncertainty.

This work is supported by the Centre for Quantum Engineering and Space-Time Research (QUEST) and the ERA-NET Plus Programme.

Q 34.83 Tue 16:30 Poster.I+II

Frequenzkämme für μ-g Experimente — •Tobias Wilken[1,2], Matthias Lezius[2], Theodor W. Hänsch[1], and Ronald Holzwarth[1,2] — [1]MPQ, Garching — [2]Menlosystems GmbH, Martinsried

Im Rahmen des Projektes FOKUS (Faserlaserbasierter Optischer Kammgeneratur unter Schwerelosigkeit) wird eine Frequenzkamm entwickelt, der auf einer sounding rocket Mission eingesetzt werden kann. Wir haben einen 100MHz Kammsystem - basierend auf polarisationserhaltenden Fasern - aufgebaut, das alle Anforderungen erfüllt um den Raketenstart sowie die μ-g Phase zu überstehen. Vibrations- und Thermaltests wurden durchgeführt um dies zu bestätigen. Die Optik wurde miniaturisiert und passt in einen Zylinder von ca. 20cm Durchmesser und 2cm Höhe. Der Frequenzkamm inklusive Steuerelektronik soll bis Mitte 2012 betriebsbereit sein um 2013 auf einer sounding rocket Mission mitzufliegen.

Q 34.84 Tue 16:30 Poster.I+II

Towards a test of the Universality of Free Fall with atoms in a drop tower — •Sascha Kulas, Andreas Resch, Marcus Stadtlander, and Sven Herrmann — ZARM, Universität Bremen

The enhanced free fall time which can be achieved in a microgravity environment is expected to be of great benefit to matter wave precision measurements. Many of the necessary technological developments for such experiments and first promising results have been achieved by the QUANTUS collaboration in recent years [1]. Within the PRIMUS project (Präzisions-Interferometrie unter Schwerelosigkeit) we specifically aim to further explore this potential in a dedicated drop tower experiment, using a dual species interferometer which shall compare the free fall of ^{87}Rb and ^{39}K atoms. Here we present the current status of this experiment and discuss the perspectives and attainable sensitivity of such a free fall test in the Bremen Drop Tower. In addition we report on the development of metrological tools for this kind of experiment, i.e. operation of an optical frequency comb and optical cavities in the drop tower. The PRIMUS 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 1142.

[1] T. van Zoest et al., "Bose-Einstein condensation in microgravity", Science, vol 328, no. 5985, p. 1540, 2010

Q 34.85 Tue 16:30 Poster.I+II

High performance iodine frequency reference — •Matthias Reggentin[1], Klaus Döringshoff[1], Moritz Nagel[1], Evgeny V. Kovalchuk[1], Thilo Schuldt[2], Anja Keetman[2], Claus Braxmaier[2], and Achim Peters[1] — [1]Humboldt-Universität zu Berlin, Institut für Physik, AG Optische Metrologie, Newtonstr. 15, 12489 Berlin — [2]University of Applied Sciences Konstanz (HTWG), Institute of Optical Systems, 78462 Konstanz

Frequency references based on hyperfine-resolved molecular transitions in molecular iodine ($^{127}I_2$) can provide high long-term stability required for future space missions like the Laser Interferometer Space Antenna (LISA).

For this purpose we stabilize a frequency doubled 1064 nm Nd:YAG laser to the a_{10} component of the R(56)32-0 transition of $^{127}I_2$ by applying Modulation Transfer Spectroscopy. Using a 80 cm long iodine cell within our setup we have achieved a frequency stability of 2×10^{-14} at 1 s and 3×10^{-15} between 50...5000 s. We discuss the recent progress in improving the laboratory setup and in evaluating further limitations and influences on its frequency stability by studying selected subsystems and components. Furthermore we present investigations for the development of a semi-monolithic setup based on adhesive bonded ceramics providing compactness and high thermal as well as mechanical stability.

This work is supported by the German Space Agency DLR with funds provided by the Federal Ministry of Economics and Technology (BMWi) under grant numbers 50 QT 1102 and 50 OQ 0601.

Q 34.86 Tue 16:30 Poster.I+II

Precision spectroscopy of atomic hydrogen: 2s-4p transition — Axel Beyer[1], Arthur Matveev[1], Christian G. Parthey[1], Nikolay Kolachevsky[1], •Janis Alnis[1], Thomas Udem[1,2], and Theodor W. Hänsch[1,2] — [1]MPI of Quantum Optics, 85748 Garching — [2]Ludwig-Maximilians-University, 80799 Munich

Atomic hydrogen is the simplest atom allowing to make stringent tests of bound state QED. 1s-2s transition frequency measurement in atomic hydrogen has recently been evaluated with 4.2×10^{-15} uncertainty or 2 466 061 413 187 035 (10) Hz for the hyperfine centroid [1].

As a next task we will re-measure more precisely transitions between higher-lying states. In the present contribution we will report on measurements of a single-photon transition between the 2s and 4p states.

Measurement of several transition frequencies in atomic hydrogen could possibly help to understand the discrepancy between proton charge radius obtained from muonic hydrogen experiment [2] and the CODATA 2010 value.

[1] C.G. Parthey *et al.*, Phys. Rev. Lett. **107**, 203001 (2011)

[2] R. Pohl *et al.*, Nature **466**, 7303 (2010).

Q 34.87 Tue 16:30 Poster.I+II

A mobile high-precision atom interferometer to measure local gravity — •Matthias Hauth, Vladimir Schkolnik, Christian Freier, Alexander Senger, Malte Schmidt, and Achim Peters — Humboldt-Universität zu Berlin, Institut für Physik, AG Optische Metrologie, Newtonstr. 15, 12489 Berlin

GAIN (Gravimetric Atom Interferometer) is a mobile and robust gravimeter that is being developed for precision measurements of the gravitational field. It is based on ensembles of laser cooled ^{87}Rb atoms which interfere in a Mach-Zehnder type interferometer realized by means of Raman transitions between the hyperfine ground states.

Here we present the latest version of our experimental setup that has reached a sensitivity of $2x10^{-8}g/\sqrt{Hz}$ during the first measurement campaign. We discuss ongoing work, as well as future improvements, to reach our targeted absolute accuracy of a few parts in 10^{10}. These include an upgrade of our active vibration isolation system, which has an effective resonance frequency of less than 1/30 Hz, by an active tilt unit compensating for phase shifts due to Coriolis forces.