A 28: Poster Session - Atomic Physics IV

Time: Thursday 16:00–18:00 Location: Empore Lichthof

A 28.1 Thu 16:00 Empore Lichthof

Strong interacting polaron and bi-polaron in 1D: beyond the extended Fröhlich model — •Martin Will[1], Jonas Jager[2], Ryan Barnett[2], and Michael Fleischhauer[1] — [1]Department of Physics and Research Center OPTIMAS, University of Kaiserslautern, 67663 Kaiserslautern, Germany — [2]Department of Mathematics, Imperial College London, London SW7 2AZ, United Kingdom

We discuss the interaction of mobile impurities with a surrounding condensate in 1D. For a large impurity-condensate coupling the usual approach of linearizing around a constant condensate density (extended Fröhlich model) does not account correctly for deformations of the BEC and is therefore no longer applicable. We give an alternative approach, taking into account the condensate deformation already on a mean field level, which can be solved analytically [1]. The energy and effective mass of the polaron quasi-particle agree well with quasi exact quantum Monte-Carlo calculations and improve substantially on approaches based on an undepleted BEC [2]. We present the mean-field solution for one as well as two impurities immersed in the condensate from which an effective impurity-impurity interaction potential, mediated through the condensate, is derived.

[1] V. Hakim Phys. Rev. E 55, 2835-2845 (1997)
[2] F. Grusdt, G. Astrakharchik, E. Demler New J. of Phys. 19.10, 103035 (2017)

A 28.2 Thu 16:00 Empore Lichthof

Engineering of vibrational dynamics in a two-dimensional array of trapped ions — •Deviprasath Palaini, Matthias Wittemer, Frederick Hakelberg, Florian Hasse, Philip Kiefer, Ulrich Warring, and Tobias Schaetz — Albert-Ludwigs-Universität Freiburg, Physikalisches Institut, Hermann-Herder-Strasse 3, 79104 Freiburg

Trapped ions present a promising system for quantum simulations. Surface-electrode traps in contrast to conventional ion traps offer the advantage of scalability to larger system size and dimension while maintaining individual control: Dedicated radio-frequency electrode shapes allow the creation of two-dimensional arrays of individual micro traps, while control electrodes allow localised manipulation of the trapping potential tuning motional frequencies and mode orientations. Our setup consists of a basic but scalable array of three Mg^+ ions individually trapped in an equilateral triangle with 40μm inter-site distance. We present the first realisation of inter-site coupling, until now only realised for linear arrangements. We demonstrate its tuning in real time, and show interference of large coherent states [1]. Furthermore we employ the individual control for modulation of the local trapping potentials to realise phonon-assisted tunnelling between adjacent sites [2].

[1] Hakelberg, F. et al. Phys. Rev. Lett. 123, 100504 (2019)
[2] Kiefer, P. et al. Phys. Rev. Lett. 123, 213605 (2019)

A 28.3 Thu 16:00 Empore Lichthof

Ultracold bosonic ^{23}Na^{39}K spin polarized ground state molecules and collisional properties in an atomic ensemble — •Philipp Gersema, Kai Konrad Voges, Mara Meyer zum alten Borgloh, Torsten Hartmann, Torben Alexander Schulze, Alessandro Zenesini, and Silke Ospelkaus — Institute of Quantum Optics, Leibniz University Hannover

Ultracold polar ground state molecules provide an excellent basis for the studies of quantum chemistry and exotic dipolar quantum phenomena. Rovibrational NaK ground state molecules feature a large dipole moment as well as chemical stability against exchange reactions. While the fermionic isotope combination ^{23}Na^{40}K has been subject to several previous studies, investigations of the bosonic combination remained elusive.

We present for the first time the production of bosonic spin polarized ground state molecules, by transferring weakly bound molecules to the absolute ground state, utilizing the stimulated Raman adiabatic passage (STIRAP). Starting from an ultracold atomic ensemble we use a Feshbach resonance to create weakly bound molecules. Spectroscopic studies of the excited B1Π and c3Σ manifold and the X1Σ ground state of the NaK molecule were performed to find a bridging state between the triplet dominated weakly bound dimers and the singlet ground state. The STIRAP pulse is done within $12\,\mu$s and has an efficiency of around 70 %, creating up to 4200 molecules. Finally we investigate the collisional properties of the ground state molecules in the 1064 nm optical dipole trap with and without atoms in different spin states.

A 28.4 Thu 16:00 Empore Lichthof

Cloud shape of a molecular Bose-Einstein condensate in a disordered trap — •Sian Barbosa[1], Benjamin Nagler[1,2], Milan Radonjic[1,3], Jennifer Koch[1], Axel Pelster[1], and Artur Widera[1,2] — [1]Department of Physics and Research Center OPTIMAS, Technische Universität Kaiserslautern, 67663 Kaiserslautern, Germany — [2]Graduate School Materials Science in Mainz, Gottlieb-Daimler-Straße 47, 67663 Kaiserslautern, Germany — [3]Scientific Computing Laboratory, Center for the Study of Complex Systems, Institute of Physics Belgrade, University of Belgrade, Serbia

The use of random potentials in experiments with ultracold atoms has proven to be a powerful tool to study disordered quantum systems. Here, we present our investigation of the static geometric properties of a harmonically trapped Bose-Einstein condensate of lithium-6 molecules in an optical speckle potential. We measure the in-situ column density profiles and the corresponding transverse cloud widths over many speckle realizations. We compare the measured widths with a theory that is non-perturbative with respect to the disorder and includes quantum fluctuations. In addition, we present a novel method to calibrate the optical speckle potential.

A 28.5 Thu 16:00 Empore Lichthof

Transport of a low-energy ion in a Bose-Einstein condensate. — •Moritz Berngruber, Thomas Dieterle, Felix Engel, Christian Hölzl, Tilman Pfau, and Florian Meinert — 5. Physikalisches Institut and Center for Integrated Quantum Science and Technology, Universität Stuttgart, Stuttgart, Germany

We study the transport properties of a cold ionic impurity in a Bose-Einstein condensate. To this end, we generate a single low-energy ion in an ultra-cold atomic sample starting from a single Rydberg excitation and investigate the interaction between the ionic impurity and the surrounding ground-state atoms. To produce the cold ion, we use methods relying either on a tailored photo-ionization scheme or field ionization. Subsequently the ion is dragged through the Bose-Einstein condensate by applying a weak electric field. Our experiments reveal strong deviations from a bare ballistic motion due to frequent ion-atom collisions and indicate diffusive transport. Furthermore, we discuss the role of three-body recombination on the transport dynamics.

A 28.6 Thu 16:00 Empore Lichthof

Shaping and Isotope-Purification of Ba^+ Ion Coulomb Crystals — •Daniel Hönig[1], Fabian Thielemann[1], Pascal Weckesser[1], Kai Lok Lam[1], Julian Schmidt[2], Leon Karpa[1], and Tobias Schätz[1] — [1]Albert-Ludwigs Universität Freiburg — [2]Laboratoire-Kastler-Brossel, Paris, Frankreich

Trapped ion Coulomb crystals are an interesting platform for quantum simulations. In order to study the dynamics of these crystals e.g. during structural phase transitions, robust methods for isotope-selective preparation as well as control over the ion number are needed.

We present two different methods for reliable ion removal: For isotope selectivity we use parametric excitation of the ions in a Paul trap. Here we achieve a mass resolution high enough to separate $^{137}Ba^+$ and $^{138}Ba^+$, reliably removing the unwanted isotope from the trap. The second method uses state-selective potentials within a 532nm single beam optical dipole trap. By preparing single ions of an ion Coulomb crystal in the $6S_{1/2}$ electronic ground state or the metastable $5D_{5/2}$ state, the dipole trap is attractive or repulsive, respectively. By pumping individual ions into the metastable state we can deterministically remove a single ion of choice.

On the poster we will present our experimental setup. Both theoretical simulations, as well as experimental data concerning the performance will be presented.

A 28.7 Thu 16:00 Empore Lichthof

Ultracold interaction between a single Ba^+-ion and spin-polarized Li — •Fabian Thielemann[1], Pascal Weckesser[1], Daniel Hoenig[1], Kai Lok Lam[1], Markus Debatin[1,2], Leon Karpa[1], and Tobias Schaetz[1] — [1]Physikalisches Institut, Albert-

Ludwigs Universität Freiburg — [2]Institut für Physik, Universität Kassel

The fields of ultracold atoms and trapped ions are important pillars of experimental quantum optics. Recently the expertise of both fields has been combined in hybrid trapping setups to prepare atom-ion mixtures at low temperatures. For joint systems features like Feshbach resonances at magnetic fields on the order of tens of Gauss and the formation of mesoscopic, weakly bound molecules have been predicted. As a first step towards this regime, reaching temperatures on the order of few μK in the combined system is necessary.

Here we present results of a single Ba^{+}-ion immersed in a cloud of fermionic Li. We observe that, depending on parameters such as the density of the atomic gas or the intensity of present light fields, the ion either undergoes chemical reactions or elastic collisions that result in sympathetic cooling. Further, we present a method that we developed to deterministically prepare a single ion in an rf or optical trap. In this method we make use of state dependent potentials in optical traps to eject selected ions from the trap.

A 28.8 Thu 16:00 Empore Lichthof

Loading of sub-Doppler cooled potassium-39 ensembles into a painted optical dipole trap — •Alexander Herbst, Henning Albers, Sebastian Bode, Knut Stolzenberg, Ernst M. Rasel, and Dennis Schlippert — Institute of Quantum Optics, Leibniz University Hannover

The all-optical creation of potassium BECs is of large interest for the field of guided atom interferometry and its application for quantum inertial sensors as this technique allows for the use of external magnetic fields to control inter-atomic interactions and suppress dephasing effects. However, the direct loading of a large, thermal potassium ensemble into an optical dipole trap remains a major challenge and is crucial for all following processes.

We report on the preparation of sub-Doopler cooled potassium using a gray molasses technique on the D1-line and its loading into an optical dipole trap at 2 um wavelength. Utilizing a time-averaged potential we are able to generate different trap geometries with position-depending AC-Stark-shifts. We analyze the resulting effects on the loading and cooling efficiency of the D1-scheme and discuss possible applications for traditional sub-Doppler schemes.

This work is funded by the Federal Ministry of Education and Research (BMBF) through the funding program Photonics Research Germany (contract number 13N14875), and the DFG under Germany's Excellence Strategy (EXC 2123) "QuantumFrontiers".

A 28.9 Thu 16:00 Empore Lichthof

The Bose-Einstein and Cold Atom Laboratory (BECCAL) for the ISS — •Kai Frye[1], Tom-Marvin Rathmann[1], Daniel Röckrath[1], Hemanth Kalathur[1], Dennis Becker[1], Christian Schubert[1], Waldemar Herr[1], Sven Abend[1], Thijs Wendrich[1], Ernst Rasel[1], and BECCAL Team[1,2,3,4,5,6] — [1]Leibniz University Hannover — [2]University Ulm — [3]FBH Berlin — [4]Humboldt University Berlin — [5]Johannes Gutenberg-University Mainz — [6]ZARM, University Bremen

Microgravity enables a long free fall of matter waves and eliminates the gravitational sag in traps for atoms. An in-orbit accommodation for microgravity experiments is provided by the International Space Stations.

We present the multi-user and -purpose facility Bose-Einstein Condensate and Cold Atom Laboratory (BECCAL), a joint DLR and NASA project. This apparatus opens up a vast variety of experiments on atom interferometry, atom optics, physics of quantum degenerate gases and their mixtures. These experiments will be a stepping stone for future missions advancing quantum technology for space.

The scientific capabilities and the design of the physics package subsystem as well as our solutions to the constraints set by an accommodation aboard the International Space Station and our approach to establish a multi-user facility is presented.

The BECCAL project is supported by the DLR with funds by the BMWi under grant numbers 50 WP 1431 and 1700. We acknowledge support by QuantumFrontiers under grant number EXC-2123.

A 28.10 Thu 16:00 Empore Lichthof

Creation and splitting of quantum degenerate gases in painted optical potentials - a toolbox for guided atom interferometry — •Knut Stolzenberg, Sebastian Bode, Alexander Herbst, Henning Albers, Ernst M. Rasel, and Dennis Schlippert — Institute of Quantum Optics, Leibniz University Hannover

Guided atom interferometers promise to be compact and robust inertial sensors with excellent long-term stability. An acousto-optic deflector (AOD) is used to create arbitrary time averaged optical dipole potentials by diffracting the beam of a high power 1064 nm laser. This allows for (i) a fast evaporation to quantum degeneracy of ^{87}Rb and (ii) the generation of multiple distinct potential wells. The latter are utilized to split and guide the ensemble. After a free evolution time of $T = 1$ s the clouds are spatially overlapped and interference patterns are observed. We show first results in single and differential matter wave interferometer configuration with magnetically sensitive and insensitive states and discuss future prospects of fully guided interferometry.

This work is funded by the Federal Ministry of Education and Research (BMBF) through the funding program Photonics Research Germany (contract number 13N14875), and the DFG under Germany's Excellence Strategy (EXC 2123) "QuantumFrontiers".

A 28.11 Thu 16:00 Empore Lichthof

Inter-orbital Interactions in a Fermionic Ytterbium Mixture — •Marcel Diem[1], Benjamin Abeln[1], Koen Sponselee[1], Nejira Pintul[1], Klaus Sengstock[1,2], and Christoph Becker[1,2] — [1]Center for Optical Quantum Technologies, University of Hamburg, Luruper Chaussee 149, 22761 Hamburg — [2]Institute for Laserphysics, University of Hamburg, Luruper Chaussee 149, 22761 Hamburg

We present measurements on the inter-orbital interactions between $^1S_0$ ground state and $^3P_0$ metastable state atoms in different fermionic Ytterbium mixtures. We use clock transition spectroscopy in a three-dimensional optical lattice to determine the s-wave scattering lengths. Our first set of measurements is on the spin-exchange interaction of the fermionic Isotope ^{171}Yb. The interaction is antiferromagnetic, which makes ^{171}Yb a promising candidate for the quantum simulation of the Kondo lattice model. Our second set of measurements is on inter-orbital interactions in an SU(2) × SU(6) fermionic mixture of ^{171}Yb and ^{173}Yb. We measure the different interaction strengths and show its SU(N) symmetry.

A 28.12 Thu 16:00 Empore Lichthof

Sound in a Homogeneous Bose Gas - The Two Fluid Model and Nonlinear Damping — •Timon Hilker[1], Christoph Eigen[1], Jinyi Zhang[1], Lena Dogra[1], Jake Glidden[1,2], Robert Smith[1,2], Nir Navon[1,3], and Zoran Hadzibabic[1] — [1]Cavendish Laboratory, University of Cambridge, UK — [2]Clarendon Laboratory, University of Oxford, UK — [3]Department of Physics, Yale University, New Haven, CT USA

The existence of two distinct sound velocities is one of the hallmarks of superfluids. In a compressible quantum gas both modes couple to density, which allows us to observe, for the first time, both sound velocities in a moderately interacting ultracold Bose gas. Using a magnetic field gradient, we excite centre-of-mass oscillations of a homogeneous K-39 Bose gas in a three-dimensional box trap, revealing two distinct resonant oscillations as described by Landau's two-fluid model. We study the speed, the damping and the microscopic structure of both modes for various interaction strengths and temperatures. At zero temperature, all standard damping vanishes for the lowest BEC mode giving us the unique opportunity to investigate purely nonlinear damping due to collisional coupling to higher modes.

A 28.13 Thu 16:00 Empore Lichthof

Setting up a sideband system and a digital ion trap in an atom-ion hybrid experiment — •Dominik Dorer, Shinsuke Haze, Joschka Wolf, Markus Deiss, and Johannes Hecker Denschlag — Institut für Quantenmaterie, Universität Ulm, 89069 Ulm, Germany

We report on two ongoing projects in our atom-ion hybrid trap experiment. First, we want to present the progress for implementing a resolved sideband cooling system for $^{138}Ba^{+}$ ions. For this we implement a narrow band laser addressing the $6S_{1/2} \rightarrow 5D_{5/2}$ shelving transition at 1762 nm. To achieve a linewidth much smaller than the typical trapping frequencies of our Paul trap (40 kHz) and a daily frequency shift in the sub kHz-regime, we set up a high-Q optical cavity made of ultra low expansion glass. We tested this optical cavity and have carried out first measurements of the shelving transition.

Second, we present our approach to realize a digital ion trap, which we want to use to perform Stark spectroscopy of Rydberg atoms in the electric field of trapped ions [1]. The strategy is to pulse the Rydberg excitation laser in periods where there is no electric field of the ion trap.

[1] S. Haze et al., arXiv 1901.11069 (2019)

A 28.14 Thu 16:00 Empore Lichthof

Scattering an atom from a Rydberg composite — •Rajat Agrawal and Jan Michael Rost — Max Planck Institute for the Physics of Complex Systems, Dresden, Germany

Here we analyze the collision of a slow atom with a 2D Rydberg composite [1] (changes the electron density of the composite). We will discuss the collision for different geometries like the atomic lattice of Rydberg composites is perpendicular and parallel to the trajectory of an atom. We will also discuss the lattice of the Rydberg composite which has just a single ground state atom (trilobite limit).

[1] Andrew L. Hunter, arXiv:1909.01097v1 (2019)

A 28.15 Thu 16:00 Empore Lichthof

Emergence of the Higgs mode in a two-dimensional few-fermion system — •Keerthan Subramanian, Luca Bayha, Marvin Holten, Ralf Klemt, Philipp Preiss, and Selim Jochim — Physikalisches Institut, Universität Heidelberg, 69120 Heidelberg, Germany

Knowledge of collective excitations is indispensable for many-body systems since they can be used to determine the low-energy properties of the system while being completely ignorant of the dynamics of microscopic constituents. But how many constituents does a system have to contain to be considered many-body?

To gain an insight into this question, we study excitations of an ultracold few-fermion system consisting of ^{6}Li atoms. We first deterministically prepare few atoms in closed shell configurations of a 2D harmonic trapping potential and then excite the system by modulating interactions. We find that the lowest monopole mode shows a non-monotonic behavior and is composed predominantly of pair-excitations prescient of Higgs mode in the many-body limit. This resemblance to the Higgs mode becomes more striking with increasing particle number as more shells of the 2D harmonic oscillator are populated. We further find that the precursor to the Higgs mode can be coherently driven since it does not couple to other modes.

Future directions of investigation will involve spin-resolved single particle imaging of the system to observe Cooper paring and the onset of superfluidity.

A 28.16 Thu 16:00 Empore Lichthof

Interorbital spin-exchange dynamics in ultracold ytterbium — •Giulio Pasqualetti[1,2,3], Oscar Bettermann[1,2,3], Nelson Darkwah Oppong[1,2,3], Luis Riegger[1,2,3], Immanuel Bloch[1,2,3], and Simon Fölling[1,2,3] — [1]Max-Planck-Institut für Quantenoptik, Garching, Germany — [2]Ludwig-Maximilians-Universität, Munich, Germany — [3]Munich Center for Quantum Science and Technology, Munich, Germany

With an ultranarrow clock transition, ultracold ytterbium is a promising candidate for quantum simulation of impurity physics, where atoms in a "clock" state represent the impurities, and atoms in the ground state play the role of conduction electrons. The interorbital spin-exchange interaction of ytterbium-171 has recently been measured and proved to be antiferromagnetic, complementing the already known ferromagnetic value of ytterbium-173. Such an interaction is very similar to the one responsible in condensed matter for the Kondo effect, where spin-spin interaction dominates the interplay between localized magnetic moments and the conduction bath. In our experiment, we utilize state-dependent lattices to localize dilute "clock" impurities, and we investigate spin-exchange dynamics of ytterbium in a variety of regimes. Our work presents some milestones towards the quantum simulation of strongly-correlated many-body electronic systems and, in particular, Kondo physics with ultracold atoms.

A 28.17 Thu 16:00 Empore Lichthof

Engineering time-dependent disorder potentials for fermionic quantum gases — •Silvia Hiebel[1], Benjamin Nagler[1,2], Jennifer Koch[1], Sian Barbosa[1], and Artur Widera[1,2] — [1]Department of Physics and Research Center OPTIMAS, Technische Universität Kaiserslautern, Germany — [2]Graduate School Materials Science in Mainz, Gottlieb-Daimler-Strasse 47, 67663 Kaiserslautern, Germany

While ultracold atomic gases in static random potentials have facilitated the investigation of Anderson and many-body localization, the impact of time-dependent disorder onto quantum systems is yet a new and uncharted territory.

We have developed a scheme to produce time-dependent optical speckle disorder by combining a stationary with a rotating diffuser. The diffusers are illuminated by a beam of coherent light, onto which they imprint a spatially and temporally varying phase. Subsequently, the light is focused onto the position of the atoms, which experience a dynamic speckle potential. The characteristic time scale of the dynamics is given by the rotation speed of the diffusor and, thus, can be tuned in broad range of parameters to match typical time scales of the quantum gas.

Here we present a characterization of the speckle pattern together with a characterization of the quantum gas in order to identify optimum parameters for the investigation of nonequilibrium physics in interacting quantum gases.

A 28.18 Thu 16:00 Empore Lichthof

Roadmap to Rb-Sr dipolar rovibronic ground-state molecules — •premjith thekkeppatt, lukas reichsöllner, vincent barbé, severin charpignon, benjamin pasquiou, klaasjan van druten, and florian schreck — Van der Waals-Zeeman Institute, Institute of Physics, University of Amsterdam

Ultracold dipolar molecules offer an ideal platform for investigations in the fields of quantum simulation, precision measurements and quantum chemistry. Thus far, the ultracold polar molecules that have been produced are closed-shell molecules, which limits their range of application. Our goal is to produce RbSr ultracold, polar, open-shell molecules, in order to extend the range of possibilities offered by ultracold molecular physics. We present an efficient quantum-engineering approach to the production of RbSr molecules. The first step is the creation of Rb-Sr atom pairs in the ground-state of an optical lattice, starting from quantum-degenerate clouds of 87Rb and 84Sr. The following step is the magneto-association of these atom pairs into weakly-bound molecules, using a magnetic Feshbach resonance that we identified and that should allow efficient molecular association. With this aim, we designed a highly stable power supply for high magnetic fields, in order to achieve efficient adiabatic transfers from the atom pair state to the weakly-bound molecular state. We describe the laser system that we intend to use for the final step of the molecule production, which is the coherent state-transfer to the rovibronic ground-state using STImulated Raman Adiabatic Passage (STIRAP).

A 28.19 Thu 16:00 Empore Lichthof

Single-atom-resolved fluorescence detection in a magneto-optical trap — •Cebrail Pür, Mareike Hetzel, Jiao Geng, Andreas Hüper, Wolfgang Ertmer, and Carsten Klempt — Institut für Quantenoptik, Leibniz Universität Hannover, Welfengarten 1, D-30167 Hannover, Germany

Atom interferometers, which belong to today's most precise sensors, are fundamentally limited by the standard quantum limit (SQL $\propto 1/\sqrt{N}$) when operated with uncorrelated particles. Within our project, we will employ spin-dependent collisional interactions in Bose-Einstein condensates to generate metrologically useful entanglement to overcome this limitation. The new level of precision is then given by the Heisenberg limit, which necessitates the precise determination of the atom number with an error below the single atom level. In a new dedicated apparatus we demonstrate our single-particle resolving detection scheme with fluorescence imaging of a 3D-MOT filled with ^{87}Rb atoms. In contrast to absorption imaging, the signal-to-noise ratio (SNR) is greatly enhanced due to the long lifetime of the MOT and the large signal of photons scattered per atom and per unit time.

Single-particle resolving fluorescence measurements for up to 30 atoms are presented. According to our noise analysis the single-atom resolution extends to a limiting atom number of 390(20) atoms. The variance in atom number resolution is currently restricted by the stability of our laser frequency and intensity, which will be improved by active stabilization. We outline a path to approach the Heisenberg limit in phase sensitivity with mesoscopic ensembles.

A 28.20 Thu 16:00 Empore Lichthof

Spontaneous density-modulation through Rydberg dressing: Cluster Gutzwiller mean-field study of a Bose-Hubbard model with next-nearest neighbor interaction — •Mathieu Barbier, Jaromir Panas, and Walter Hofstetter — Goethe Universität, Frankfurt am Main, Deutschland

Recently it became possible to experimentally create macrodimers in a lattice through coupling of an ultracold bosonic quantum gas to high lying Rydberg states[1]. As a follow-up study, it was proposed to use the coupling to macrodimer states for the enhancement of Rydberg dressing schemes, which might lead to a rich phase diagram of nontrivial quantum phases.

We theoretically study a bosonic quantum gas trapped in an optical lattice with weak Rydberg dressing, resulting in an effective next-nearest neighbor interaction. In this work we consider both attractive and repulsive interaction. In order to capture additional quantum fluctuations and the expected broken translational symmetry, we treat the system with the Cluster Gutzwiller method [2].

We find various quantum phases, such as Mott insulating and superfluid phases as well as density wave phases between the Mott lobes that are stabilized by hopping processes. We propose how to access these phases with a range of experimentally feasible parameters.

[1] S. Hollerith *et al.*, Science **364**, 664 (2019)
[2] D. Lühmann, Phys. Rev. A **87**, 043619 (2013)

A 28.21 Thu 16:00 Empore Lichthof

Number squeezing transfer from spin to momentum states — •Alexander Idel[1], Fabian Anders[1], Polina Feldmann[2], Bernd Meyer[1], Jan Peise[1], Luis Santos[2], and Carsten Klempt[1] — [1]Institut für Quantenoptik, Leibniz Universität Hannover — [2]Institut für theoretische Physik, Leibniz Universität Hannover

Twin-Fock states can measure the phase of an interferometer more precise than the standard quantum limit (SQL)[1]. Future large-scale atomic gravimeters will employ Bose-Einstein condensed samples due to their well-controlled spatial mode and the low expansion rates. Entangled states such as Twin-Fock states can be used to overcome the SQL in these interferometers. Atomic entangled states are commonly produced in the spin degree of freedom and concepts for their transfer to momentum states have not been demonstrated so far. We apply Raman laser pulses to couple the internal spin state to external momentum states. I will show first results on the entanglement verification and a possible extension of the concept to atomic gravimetry beyond the SQL.

[1] B. Lücke *et al, Science*, **334**, 6057 (2011).

A 28.22 Thu 16:00 Empore Lichthof

A trapped dipolar supersolid with atomic Dysprosium — •Kevin Ng[1], Mingyang Guo[1], Fabian Böttcher[1], Jens Hertkorn[1], Jan-Niklas Schmidt[1], Hans Peter Büchler[2], Tim Langen[1], and Tilman Pfau[1] — [1]5. Physikalisches Institut and Center for Integrated Quantum Science and Technology IQST, Universität Stuttgart — [2]Institute for Theoretical Physics III and Center for Integrated Quantum Science and Technology IQST, Universität Stuttgart

A supersolid is a counter-intuitive state of matter that combines the frictionless flow of a superfluid with the crystal-like periodic density modulation of a solid. Although first predicted to exist over 50 years ago, recent efforts to realize such a state have not exhibited propagating phonon modes. With a self-organized array of dipolar quantum droplets, we demonstrate the first true realization of a supersolid state, where global gauge symmetry and translational symmetry are simultaneously broken.

In our system, a periodic density modulation arises from intrinsic interactions between atoms. This, and in addition to global phase coherence, we observe the Goldstone mode associated with two broken translational symmetries. This low-energy mode, existing only as a consequence of superfluid stiffness, features an out-of-phase oscillation of the crystal array and the superfluid density while keeping the center-of-mass constant. At the phase transition between BEC and supersolid phases, we identify the low-energy Goldstone and Higgs amplitude modes as emerging from the softening roton modes of the dipolar BEC.

A 28.23 Thu 16:00 Empore Lichthof

A cooperative optical mirror formed by a subradiant subwavelength atomic array — •David Wei[1], Jun Rui[1], Antonio Rubio-Abadal[1], Simon Hollerith[1], Kritsana Srakaew[1], Simon Evered[1], Immanuel Bloch[1,2,3], and Christian Gross[1] — [1]Max-Planck-Institut für Quantenoptik, Garching, Germany — [2]Fakultät für Physik, Ludwig-Maximilians-Universität, München, Germany — [3]Munich Center for Quantum Science and Technology (MCQST), München, Germany

Ensembles of closely spaced quantum emitters can respond cooperatively due to photon-mediated dipole-dipole interactions. Using atomic dipoles trapped in an optical lattice, we realize a two-dimensional subwavelength square array, which shows strong subradiant response and acts as a single-layered cooperative optical mirror.

By varying the density and the ordering of the atoms in the array, we are able to control the influence of the dipolar interactions and to study the role of spatial order for the collective properties. Using Bloch oscillations to change the atom positions, we dynamically modify the reflectivity of the atomic mirror due to breaking and restoring the array order. Our work demonstrates efficient optical meta-material engineering which might give rise to novel atomic light-matter interfaces.

A 28.24 Thu 16:00 Empore Lichthof

Building up a modular Na-K quantum gas experiment — •Lilo Höcker, Jan Kilinc, Rohit Prasad Bhatt, and Fred Jendrzejewski — Kirchhoff-Institute for Physics, Im Neuenheimer Feld 227, D-69120 Heidelberg

Ultracold quantum gases allow a precise control over experimental parameters enabling the simulation of complicated physical processes in nature. Adding a second atomic species offers a versatile experimental platform to study strongly interacting many-body phenomena extending the large range of applications. In this poster, we present the new Na-K experiment at Heidelberg, which we are setting up as a platform to study quantum many-body physics like quantum thermodynamics, lattice gauge theories, Kondo effect.

A 28.25 Thu 16:00 Empore Lichthof

A laser system for creating ground state ^{23}Na^{40}K molecules — •Akira Kamijo[1], Roman Bause[1], Xing-Yan Chen[1], Marcel Duda[1], Andreas Schindewolf[1], Immanuel Bloch[1,2], and Xin-Yu Luo[1] — [1]Max-Planck-Institut für Quantenoptik, Garching, Germany — [2]Ludwig-Maximilians-Universität, München, Germany

Ultra-cold polar molecules in their ground state offer unique possibilities to investigate quantum many-body systems due to their long-ranged dipole-dipole interaction. In our experiment, ultra-cold ^{23}Na^{40}K molecules are transferred to their electronic, vibrational and rotational ground state via stimulated Raman adiabatic passage (STIRAP). This work focuses on the design and construction of a new STIRAP system following previous work at MIT [1] and Hefei [2]. An intermediate state in the B/c manifold is used, resulting in STIRAP transitions at 805 nm and 567 nm. To generate the 567 nm laser, the output of a 1134 nm external cavity diode laser is injection amplified by a gain chip to 250 mW and subsequently converted to 567 nm light by a periodically poled Lithium Niobate waveguide. 805 nm light is generated by a diode laser and amplified by a tapered amplifier. Using only solid-state lasers allows the system to be robust and easy to maintain. To ensure mutual coherence of these lasers, they are locked to a dual wavelength ultra-low expansion cavity allowing relative line widths of 10^{12} or lower.

[1] Park, J. W. et al. Phys. Rev. Lett. 114, 205302 (2015)
[2] Liu, L. et al. Phys. Rev. Lett. 122, 253201 (2019)

A 28.26 Thu 16:00 Empore Lichthof

Towards trapping ultracold polar molecules in a dark repulsive dipole trap — •Ren-Hao Tao[1], Roman Bause[1], Marcel Duda[1], Xing-Yan Chen[1], Andreas Schindewolf[1], Immanuel Bloch[1,2], and Xin-Yu Luo[1] — [1]Max-Planck Institut für Quantenoptik, Hans-Kopfermann-Str. 1, 85748 Garching, Germany — [2]Ludwig-Maximilians-Universität München, Faculty of Physics, Schellingstrasse 4, 80799 Munich, Germany

Ultra-cold molecules, by virtue of their rich ro-vibrational states and significant dipole moments, offer us an exciting platform to study new quantum many-body physics. However, many experiments have shown loss behaviours of molecules consistent with two-body losses. For non-reactive species, this is not expected. A recent proposal suggests that the trapping light in these experiments, despite being far-detuned from molecule transitions, can still electronically excite two-molecule complexes. To test this theory, we plan to trap ^{23}Na^{40}K molecules using a blue-detuned light away from the transition $|X^1\Sigma^+, v=0, J=0\rangle \rightarrow |b^3\Pi, v=0, J=1, \Omega=0\rangle$. Such a transition, owing to its small linewidth ($2\pi \times 297$ Hz), has a low photon scattering rate even if we go near-resonant. As a result, we can trap molecules with less trapping intensity due to their large polarizability at near-detuning. We achieve a trap depth of $4k_B \cdot \mu$K with an intensity in the dark region as low as 4W/cm^2, which is much lower than the predicted threshold intensity for destroying the scattering complex of ^{23}Na^{40}K molecules.

A 28.27 Thu 16:00 Empore Lichthof

Parametric Excitation of a Bose-Einstein Condensate: From Faraday Waves to Granulation — •Axel U. J. Lode[1], Jason H. V. Nguyen[2], Henry D. Luo[2], Gustavo D. Telles[3], Vanderlei S. Bagnato[3], Marios C. Tsatsos[3], and Randy G. Hulet[2] — [1]Albert-Ludwig University, Freiburg, Germany — [2]Rice University, Houston, USA — [3]University of São Paulo, São Carlos, Brazil

We explore, both experimentally and theoretically, the response of an elongated Bose-Einstein condensate to modulated interactions. We identify two distinct regimes differing in modulation frequency and modulation strength. Longitudinal surface waves are generated either resonantly or parametrically for modulation frequencies near the radial trap frequency or twice the trap frequency, respectively. The dispersion of these waves, the latter being a Faraday wave, is well reproduced by a mean-field theory that accounts for the 3D nature of the elongated condensate. In contrast, in the regime of lower modulation frequencies, we find that no clear resonances occur, but with an increased modulation strength, the condensate forms an irregular granulated distribution that is outside the scope of a mean-field approach. We find that the granulated condensate is characterized by large quantum fluctuations and correlations, which are well described with single-shot simulations obtained from wave functions computed by a beyond-mean-field theory at zero temperature, the multiconfigurational time-dependent Hartree for bosons method. See Phys. Rev. X **9**, 011052 (2019) and http://ultracold.org

A 28.28 Thu 16:00 Empore Lichthof

QUANTUS-2 - Quantum Gases under Microgravity — •Peter Stromberger[1], Merle Cornelius[2], Julia Pahl[3], Christian Deppner[4], André Wenzlawski[1], Patrick Windpassinger[1], and the QUANTUS-Team[1,2,3,4,5,6] — [1]JGU Mainz — [2]U Bremen — [3]HU Berlin — [4]LU Hannover — [5]U Ulm — [6]TU Darmstadt

QUANTUS-2 is a mobile rubidium BEC experiment used for experiments under microgravity in the drop tower in Bremen. Using magnetic lensing we decreased the expansion rate of the BEC in all three dimensions below 100 μm/s allowing for observations after evolution times greater than 2 seconds and enhancing the sensitivity of atom interferometers. We present preparatory measurements for the implementation of a double Bragg Mach-Zehnder type interferometer (MZI) under microgravity and the determination of the gravitational acceleration with a single Bragg MZI and a matter-wave cavity gravimeter.

Furthermore, under microgravity it is possible to implement dressed state shell potentials and confining Bose gases in two dimensions. Studying a quasi two-dimensional Bose gas allows for investigation of the Berezinskii-Kosterlitz-Thouless (BKT) phase transition. We intend to create shell potentials by radio-frequency dressing of magnetic sub-states of the hyperfine ground-state. We will discuss our progress towards implementation of dressed state potentials at the QUANTUS-2 experiment and present simulations and first experimental results.

The QUANTUS project is supported by the German Space Agency DLR with funds provided by the Federal Ministry of Economic Affairs and Energy under grant numbers DLR 50 WM 1552-1557.

A 28.29 Thu 16:00 Empore Lichthof

Realization of dual-species BEC for interferometry in space — •Jonas Böhm[1], Baptist Piest[1], Maike D. Lachmann[1], Wolfgang Ertmer[1], Ernst M. Rasel[1], and The MAIUS Team[1,2,3,4,5,6,7,8] — [1]Institute of Quantum Optics, LU Hanover — [2]Department of Physics, HU Berlin — [3]ZARM, University of Bremen — [4]DLR Institute of Space Systems, Bremen — [5]Institute of Physics, JGU Mainz — [6]DLR Simulation and Software Technology, Brunswick — [7]Ferdinand-Braun-Institut, Berlin — [8]DLR MORABA, Oberpfaffenhofen

Atom interferometry is a promising tool for measurements of the gravitational constant or the UFF. As the sensitivity scales with the squared interrogation time, conducting these experiments in microgravity is of great interest. The sounding rocket mission MAIUS-A demonstrated the first creation of a BEC in space and its use as a source for atom interferometry. Here, we present the current status of the follow-up mission MAIUS-B that extends the apparatus by another species to perform interferometry with K-41 and Rb-87. The steps to create a dual-species BEC, that includes to load atoms in a 3DMOT from a cold atomic beam created in a 2D MOT and using a sequence of polarization gradient and evaporative cooling, are discussed. Optimization routines relying on machine learning algorithms are highlighted.

The MAIUS project is supported by the German Space Agency (DLR) with funds provided by the Federal Ministry of Economics and Technology (BMWi) under grant number:50WP1431.

A 28.30 Thu 16:00 Empore Lichthof

Towards Quantum Simulation of Light-Matter Interfaces with Strontium Atoms in Optical Lattices — •Jan Trautmann, Andé Heinz, Annie Jihyun Park, Florian Wallner, Eva Casotti, Neven Šantić, Immanuel Bloch, and Sebastian Blatt — Max-Planck Institute of Quantum Optics, 85748 Garching, Germany

In the last two decades, quantum simulators based on ultracold atoms in optical lattices have successfully emulated strongly correlated condensed matter systems. With the recent development of quantum gas microscopes, these quantum simulators can now control such systems with single-site resolution. Within the same time period, atomic clocks have also started to take advantage of optical lattices by trapping alkaline-earth-metal atoms such as Sr, and interrogating them with precision and accuracy at the 10^{-18} level. Here, we report on progress towards a new quantum simulator that combines quantum gas microscopy with optical lattice clock technology. We have developed in-vacuum buildup cavities with large mode volumes that will be used to overcome the limits to system sizes in quantum gas microscopes. By using state-dependent optical lattices for the clock states, we aim to emulate strongly-coupled light-matter-interfaces in parameter regimes that are unattainable in real photonic systems.

A 28.31 Thu 16:00 Empore Lichthof

Dipolar quantum mixtures of erbium and dysprosium — •Claudia Politi[2], Philipp Ilzhöfer[2], Gianmaria Durastante[1,2], Maximilian Sohmen[1,2], Arno Trautmann[2], Manfred Mark[1,2], and Francesca Ferlaino[1,2] — [1]Institut für Experimentalphysik, Universität Innsbruck, Technikerstraße 25, 6020 Innsbruck, Austria — [2]Institut für Quantenoptik und Quanteninformation, Österreichische Akademie der Wissenschaften, 6020 Innsbruck, Austria

In the last years, strongly-magnetic atoms drew great attention in the quantum-gas community motivated by the possibility of realizing exotic phases of matter arising from long-range and anisotropic dipole-dipole interactions. So far, experiments with dipolar lanthanides focused on single-species operation. We present an experimental setup, which for the first time, combines two highly magnetic atomic species, erbium and dysprosium. In order to access the numerous interesting regimes, a precise knowledge of the inter-species scattering length is essential. Several techniques are known to probe the collisional properties, including e.g. lattice modulation spectroscopy. We present an alternative method in which, making use of species-selective potentials together with theoretical simulations based on ground state calculations using an extended Gross-Pitaevskii equation, we investigate the unknown inter-species scattering length. Merging the field of dipolar quantum gases with heteronuclear mixtures makes our system an ideal candidate to study the unexplored dipolar immiscibility-miscibility phase diagram and impurity physics in dipolar gases.

A 28.32 Thu 16:00 Empore Lichthof

Supersolid states in dipolar quantum gases — •Gabriele Natale[1], Lauriane Chomaz[1], Daniel Petter[1], Alexander Patscheider[1], Rick van Bijnen[2], Manfred Mark[1,2], and Francesca Ferlaino[1,2] — [1]Institut fuer Experimentalphysik, Universitaet Innsbruck, Technikerstraße 25, 6020 Innsbruck, Austria — [2]Institut fuer Quantenoptik und Quanteninformation, Technikerstraße 21a, 6020 Innsbruck, Austria

In the last years, experiments using highly magnetic lanthanide atoms proved the existence of novel many-body quantum states, e.g. quantum droplets and dipolar supersolids. When confined in a cigar-shaped trap, quantum gases show intriguing behaviors. The excitation spectrum of the regular superfluid can develop a roton mode. When the roton mode becomes unstable, new phases can be stabilized against collapse by quantum fluctuations. We explore the steady-state behavior of an erbium quantum gas in this regime and observe a supersolid state exhibiting a density modulation with global phase coherence. In follow-up work, we investigate the spectrum of elementary excitations across the superfluid supersolid phase transition. Theoretically, we show that, when entering the supersolid phase, two distinct excitation branches appear, associated with dominant crystal and superfluid character, respectively. Experimentally, we probe compressional excitations across the phase diagram. While in the Bose-Einstein condensate regime the system exhibits an ordinary quadrupole oscillation, in the supersolid regime we observe a striking two-frequency response of the system, related to the two spontaneously broken symmetries.

A 28.33 Thu 16:00 Empore Lichthof

Rydberg impurity dynamics in Bose-Einstein Condensates —

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Rydberg atoms can be excited embedded in a Bose-Einstein Condensate (BEC) under controlled conditions, to study the coupling to phonons [1] and formation of polarons [2].

We theoretically study the short-time non-equilibrium dynamics of the coupled BEC-Rydberg system, using Gross-Pitaevskii and ogoliubov theory, and show that the BEC can act as a tracking device for Rydberg motion, akin to a Bubble chamber [3].

When the Rydberg atom is brought into a superposition of electronic states, the different coupling of the Rydberg electron to the condensate environment in those states will lead to decoherence. The resultant hybrid open quantum system then constitutes a rare occasion where both, system and environment are highly controllable and their dynamics can be read out in detail.

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