A 18: Poster: Ultra-cold atoms, ions and BEC (with Q)

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

A 18.1 Tue 17:00 C/Foyer

Interacting bosons in an optical cavity — •Dandan Su[1], Yongqiang Li[2], and Walter Hofstetter[1] — [1]Institut für Theoretische Physik, Goethe-Universität, 60438 Frankfurt am Main, Germany — [2]Department of Physics, National University of Defense Technology, Changsha 410073, People's Republic of China

We numerically simulate strongly correlated ultracold bosons coupled to a high-finesse optical cavity. Assuming that a weak classical optical lattice is added in the cavity direction, we describe this system by a generalized Bose-Hubbard model, which is solved by means of bosonic dynamical mean-field theory. For a single-mode cavity, pumped by a laser beam in the transverse direction, the complete phase diagram is established, which contains two novel self-organized quantum phases, lattice supersolid and checkerboard solid, in addition to conventional phases such as superfluid and Mott insulator [1]. At finite but low temperature, thermal fluctuations are found to enhance the buildup of these self-organized phases. We demonstrate that cavity-mediated long-range interactions can give rise to stable lattice supersolid and checkerboard solid phases even in the regime of strong s-wave scattering. In the presence of a harmonic trap, we discuss the coexistence of these self-organized phases, as relevant to experiments. Furthermore, we investigate a system of bosons coupled to two crossed cavity modes, whose axes' angle is 60 degree. We study self-organization phenomena in the resulting hexagonal lattice.

[1] Yongqiang Li, Liang He, and Walter Hofstetter, Phys. Rev. A 87, 051604(R) (2013).

A 18.2 Tue 17:00 C/Foyer

Realizing a hybrid atom-ion trap for Li and Yb^+ — •Jannis Joger, Henning Fürst, Norman Ewald, and Rene Gerritsma — Institut für Physik, Johannes Gutenberg-Universität, D-55099 Mainz, Germany

Mixtures of ultracold atomic gases and trapped ions have become a promising application for studying cold chemistry, ultra-cold collisions and quantum many-body physics [1]. Recent analysis has shown that the time-dependent trapping field of the Paul trap can cause heating in these systems. One proposed way to mitigate this problem is to employ ion-atom combinations with a large mass ratio [2]. The highest convenient mass ratio - for species that still allow for straightforward laser cooling - is ∼29, and is achieved by using the combination Yb^+ and Li. Combining ultracold Li atoms with trapped ions poses particular technical challenges. Also the application of different sub-Doppler cooling techniques for Li such as gray molasses [3] is of particular importance to produce a dense gas in the deep quantum regime. We present a hybrid atom-ion experiment for Yb^+ and Li that we are currently building up. We discuss the magnetic field coils, ion trap and dipole trap, as well as the Zeeman slower and atomic loading platform. We also introduce a two-ion-atom detector we plan to implement in the experiment.

[1] A. Härter and J. Hecker Denschlag, Contemporary Physics 55, 33 (2014)
[2] M. Cetina et al., Phys. Rev. Lett. 109, 253201 (2012)
[3] A. Grier et al., Phys. Rev. A 87, 063411 (2013)

A 18.3 Tue 17:00 C/Foyer

Ultracold bosons in lattices with long range hopping — •Jan Stockhofe[1] and Peter Schmelcher[1,2] — [1]Zentrum für Optische Quantentechnologien, Universität Hamburg — [2]The Hamburg Centre for Ultrafast Imaging

We study ultracold bosonic atoms in a tight-binding lattice with long range hopping terms. A helix lattice setup is proposed where such hoppings to far neighbors can be experimentally tuned to sizable values. In a first step, we discuss the noninteracting Bloch dynamics under the influence of a constant force [1]. A closed expression for the propagator is given, based on which we analyze the dynamics of initially Gaussian wave packets. Our findings capture the anharmonic Bloch oscillations recently observed in photonic zigzag lattices and furthermore provide a detailed quantitative description of the crossover between center of mass oscillations for wide wave packets and left-right symmetric width oscillations for narrow single site excitations. We then turn to on-site interaction effects within a bosonic mean field framework. The long range hopping in the ensuing discrete nonlinear Schrödinger model is demonstrated to severely affect the structural and stability properties of localized excitations, such as discrete breathers.

[1] J. Stockhofe, P. Schmelcher, arXiv:1411.2784 (2014).

A 18.4 Tue 17:00 C/Foyer

Degeneracy and inversion of band structure for Wigner crystals on a closed helix — •Alexandra Zampetaki[1], Jan Stockhofe[1], and Peter Schmelcher[1,2] — [1]Zentrum für Optische Quantentechnologien, Universität Hamburg, Luruper Chaussee 149, 22761 Hamburg, Germany — [2]The Hamburg Centre for Ultrafast Imaging, Luruper Chaussee 149, 22761 Hamburg, Germany

Constraining long-range interacting particles to move on a curved manifold can drastically alter their effective interactions. As a prototype we explore the structure and vibrational dynamics of crystalline configurations formed on a closed helix. We show that the ground state undergoes a pitchfork bifurcation from a symmetric polygonic to a zig-zag-like configuration with increasing radius of the helix.

Remarkably, we find that for a specific value of the helix radius, below the bifurcation point, the vibrational frequency spectrum collapses to a single frequency. This allows for an essentially independent small-amplitude motion of the individual particles and consequently localized excitations can propagate in time without significant spreading. Increasing the radius beyond the degeneracy point, the band structure is inverted, with the out-of-phase oscillation mode becoming lower in frequency than the mode corresponding to the centre of mass motion.

A 18.5 Tue 17:00 C/Foyer

Positive and negative quenches induced excitation dynamics for ultracold bosons in one-dimensional lattices — •Simeon Mistakidis[1], Lushuai Cao[1,2], and Peter Schmelcher[1,2] — [1]Zentrum für Optische Quantentechnologien, Universität Hamburg, Luruper Chaussee 149, 22761 Hamburg, Germany — [2]The Hamburg Centre for Ultrafast Imaging, Universität Hamburg, Luruper Chaussee 149, 22761 Hamburg, Germany

The correlated non-equilibrium dynamics of few-boson systems in one-dimensional finite lattices is investigated. Focusing on the low-lying modes of the finite lattice we observe the emergence of density-wave tunneling, breathing and cradle-like processes. In particular, the tunneling induced by the quench leads to a global density-wave oscillation. The resulting breathing and cradle modes are inherent to the local intrawell dynamics and related to excited-band states. Positive interaction quenches couple the density-wave and the cradle modes allowing for resonance phenomena. Moreover, the cradle mode is associated with the initial delocalization and following a negative interaction quench can be excited for incommensurate setups with filling larger than unity. For subunit and commensurate fillings it can be accessed with the aid of a negative quench of the optical lattice depth. Finally, our results shed light to possible controlling schemes for the cradle and the breathing modes in terms of the tunable parameters of the Hamiltonian. The evolution of the system is obtained numerically using the ab-initio multi-layer multi-configuration time-dependent Hartree method for bosons.

A 18.6 Tue 17:00 C/Foyer

A High-Resolution Imaging System for Ultracold Dysprosium Atoms — •Matthias Wenzel, Thomas Maier, Holger Kadau, Matthias Schmitt, Clarissa Wink, Axel Griesmaier, and Tilman Pfau — 5. Physikalisches Institut, Universität Stuttgart, Pfaffenwaldring 57, 70569 Stuttgart, Germany

Strongly dipolar quantum gases enable the observation of many-body phenomena with anisotropic, long-range interaction. Rotonic features, 2D stable solitons and the supersolid state are some of the exotic many-body phenomena predicted for dipolar quantum gases.

Recently quantum degeneracy of dysprosium, the element with the strongest magnetic dipole moment, was achieved. After preparation of a dysprosium condensate we plan to use a diffraction-limited custom objective with high numerical aperture for in-situ imaging. This allows to reveal the structure of the quantum gas on a sub-micron level. Combined with an electro-optical deflector system and a Pockels cell the objective is used to create tailored potentials. With this setup we want to investigate multi-well potentials [1] or ring-shaped potentials [2].

[1] D. Peter, K. Pawłowski, T. Pfau and K. Rzażewski, J. Phys. B, 45, 225302 (2012)
[2] M. Abad, M. Guilleumas, R. Mayol, M. Pi and D. M. Jezek, EPL, 94, 10004 (2011)

A 18.7 Tue 17:00 C/Foyer

Future prospects for trapping a single ion in Bose-Einstein condensates — •Kathrin Kleinbach, Karl Magnus Westphal, Michael Schlagmüller, Huan Nguyen, Fabian Böttcher, Tara Cubel Liebisch, Robert Löw, Sebastian Hofferberth, and Tilman Pfau — 5. Physikalisches Institut, Universität Stuttgart, Stuttgart, Germany

Creating hybrid systems of ions and neutral atoms is of great interest in order to study controlled collision and chemical processes in ultracold temperature regime. There has been exciting progress made with combining ion traps with neutral atom traps, but due to the micromotion of the ion in trap, the ultralow temperature regimes of these hybrid systems still remains out-of-reach. We propose two methods for realizing an ion-neutral hybrid system with Rydberg atoms excited in a Bose-Einstein condensate. The first approach is to excite a single Rydberg atom in the BEC and then promote it into a circular state with a radius on the order of $2\mu m$, via fast electric field pulses. The electron would then orbit outside of the BEC created with appropriate trap frequencies. The second approach would be to create the single Rydberg impurity in the BEC and then shine focused magic wavelength light on the Rydberg atom, thereby ionizing the electron and trapping the ion. The advantage of the second approach is that the ion could be held for long times and dragged through the BEC to sample various density regimes.

A 18.8 Tue 17:00 C/Foyer

Magnetic Quantum Phases of Ultracold Dipolar Gases in an Optical Superlattice — •Xiangguo Yin[1], Lushuai Cao[1,2], and Peter Schmelcher[1,2] — [1]Zentrum für Optische Quantentechnologien, Universität Hamburg, Luruper Chaussee 149, D-22761 Hamburg, Germany — [2]The Hamburg Centre for Ultrafast Imaging,Luruper Chaussee 149,D-22761 Hamburg, Germany

We propose an effective Ising spin chain constructed with dipolar quantum gases confined in a one-dimensional optical superlattice. Mapping the motional degrees of freedom of a single particle in the lattice onto a pseudo-spin results in effective transverse and longitudinal magnetic fields. This effective Ising spin chain exhibits a quantum phase transition from a paramagnetic to a single-kink phase as the dipolar interaction increases. Particularly in the single-kink phase, a magnetic kink arises in the effective spin chain and behaves as a quasi-particle in a pinning potential exerted by the longitudinal magnetic field. Being realizable with current experimental techniques, this effective Ising chain presents a unique platform for emulating the quantum phase transition as well as the magnetic kink effects in the Ising-spin chain and enriches the toolbox for quantum emulation of spin models by ultracold quantum gases.

A 18.9 Tue 17:00 C/Foyer

Out-of-equilibrium dynamics of two interacting bosons — •Tim Keller[1], Thomás Fogarty[1,2], and Giovanna Morigi[1] — [1]Theoretische Physik, Universität des Saarlandes, D-66123 Saarbrücken, Germany — [2]Quantum Systems Unit, Okinawa Institute of Science and Technology Graduate University, Okinawa, Japan

Small systems of ultracold quantum gases are a leading candidate for studying interesting quantum phenomena in interacting many-body systems. To this end we study the out-of-equilibrium dynamics of two interacting bosons in a one-dimensional harmonic trap after a quench by a delta-shaped potential located in the centre of the trap. We make use of an approximate variational calculation called Lagrange-mesh method to solve the Schrödinger equation. We examine the dynamics by calculating the single particle density and calculate the correlations between the particles via the von Neumann entropy. We investigate the irreversibility of the quenched system by calculating the Loschmidt echo. This is related to the spectral function, with which one can discern distinct scattering states created by the quench and the emergence of the orthogonality catastrophe. We show that a thorough examination of the parameter space leads to the excitation of distinct separate or collective oscillations and also the creation of NOON states depending on the interaction and strength of the quench. We also show that the distribution of the Loschmidt echo over large time scales can be used to identify different distinct regimes, which are heavily dependent on the interaction strength between the atoms.

A 18.10 Tue 17:00 C/Foyer

Sympathetic cooling of OH^--ions using Rb atoms in a MOT — •Stefan Paul[1], Bastian Höltkemeier[1], Henry Lopez[1], Pascal Weckesser[1], Matthias Weidemüller[1], Eric Endres[2], and Roland Wester[2] — [1]Physikalisches Institut, Im Neuenheimer Feld 226, 69120 Heidelberg — [2]Institut f. Ionenphysik und Angewandte Physik Universität Innsbruck Technikerstraße 25/3 A-6020 Innsbruck, Austria

We report on the current status of our experiment employing a hybrid atom-ion trap for investigating the interaction between OH^- anions and rubidium atoms. The experimental configuration consists of an octupole rf ion trap with thin wires. The design provides a large field-free center as well as sufficient optical access to combine the ion trap with a magneto optical trap (MOT) for the atoms. The MOT can be extended to a Dark Spontaneous Force Optical Trap.

A 18.11 Tue 17:00 C/Foyer

Bose-Einstein condensation in a hybrid trap for photoionization experiments — •Harry Krüger[1], Bernhard Ruff[2,3], Maik Schröder[1], Jasper Krauser[1], Philipp Wessels[1,2], Juliette Simonet[1], Markus Drescher[2,3], and Klaus Sengstock[1,2] — [1]Zentrum für optische Quantentechnologien, Hamburg, Germany — [2]Centre for Ultrafast Imaging, Hamburg, Germany — [3]Institut für Experimentalphysik, Hamburg, Germany

Local photoionization of ultracold atoms shall offer insight into the coherence properties of a Bose-Einstein condensate (BEC). To access the corresponding quantum effects, we are setting up an experiment to observe correlations among electrons originating from a BEC ionized by a femtosecond laser pulse.

We present the design of our vacuum system consisting of a preparation and a science chamber with the atom transport provided by an optical tweezers approach. The transport is necessary because usual cooling techniques are difficult to implement in the science chamber where the particle detectors have to be shielded against stray fields. To realize quantum degeneracy in the preparation chamber, we perform forced evaporative cooling in a hybrid trap consisting of a magnetic quadrupole trap combined with a red-detuned optical dipole trap. We show experimental results for the evaporation efficiency and support these data by numerical simulations of the hybrid trap potential as well as the evaporation process itself.

A 18.12 Tue 17:00 C/Foyer

An analytical approach to confinement-induced resonances in multichannel collisions — •Benjamin Hess[1], Panagiotis Giannakeas[2], and Peter Schmelcher[1,3] — [1]Zentrum für Optische Quantentechnologien, Universität Hamburg, Luruper Chaussee 149, 22761 Hamburg, Germany — [2]Department of Physics and Astronomy, Purdue University, West Lafayette, Indiana 47907, USA — [3]The Hamburg Centre for Ultrafast Imaging, Universität Hamburg, Luruper Chaussee 149, 22761 Hamburg, Germany

We perform an analytical investigation within the framework of generalized K Matrix theory of the scattering problem in tight isotropic and harmonic confinement allowing for open trap modes. The scattering behavior is explored for identical bosons and fermions, as well as for distinguishable particles, the main aspect being the confinement-induced resonances (CIR) which are attributed to different partial waves. In particular we present the unitarity bounds which emerge when considering a quasi one dimensional system. Unitarity bounds are also given for the transition coefficients, which show the limitations for efficient transversal de-excitations by means of CIRs. Furthermore, we analyze the CIR for d-waves and find the intriguing phenomenon of a strong transmission suppression in the presence of more than one open channel, which represents an interesting regime for the corresponding many-particle systems. The corresponding channel threshold singularities are studied and it is shown that these are solely determined by the symmetry class of the partial wave.

A 18.13 Tue 17:00 C/Foyer

Cavity-Optomechanics with Cold Atoms: Coupled Quantum Oscillators and Quantum Limited Force Sensing — •Nicolas Spethmann[1,2], Jonathan Kohler[1], Sydney Schreppler[1], Lukas Buchmann[1], and Dan Stamper-Kurn[1] — [1]University of California, Berkeley — [2]Universität Kaiserslautern

Cavity opto-mechanics with cold atoms provides a system with unique properties for studying quantum physics: Highly tunable and controllable oscillators, close to their thermal groundstate, with excellent isolation from the environment and quantum-limited optical detection.

The limit of sensitivity of a force measurement dictated by quantum mechanics, the standard quantum limit, is reached when measurement imprecision from photon shot-noise is balanced against disturbance from measurement back-action. To observe this quantum limit, we apply a known external force to the center-of-mass motion of an ultracold atom cloud in a high-finesse optical cavity. We achieve a sensitivity of $(42\pm13\text{yN})^2/\text{Hz}$, consistent with theoretical predictions and a factor of 4 above the absolute standard quantum limit.

The flexibility of our approach furthermore allows us to study cavity-optomechanics with multiple, coupled oscillators. We demonstrate cavity mediated coupling between two near-groundstate oscillators. We observe the oscillating coherent transfer of excitation between the oscillators. At the same time, we detect the motional noise of the oscillators to monotonously increase due to back-action caused by the coupling. Our results point to the potential, and also the challenge, of coupling quantum objects with light.

A 18.14 Tue 17:00 C/Foyer

Light induced spin-orbit coupling for ultracold neutral atoms — •Felix Kösel, Sebastian Bode, Holger Ahlers, Katerine Posso Trujillo, Naceur Gaaloul, and Ernst M. Rasel — Institut für Quantenoptik, Hannover, Germany

We present the status of our experiment for engineering 2D spin-orbit coupling [1] of a neutral Rubidium Bose-Einstein condensate. Using Raman transitions to couple cyclically three hyperfine Zeeman states of the atoms, an effective gauge field is predicted to be created which resembles the one occurring in spintronic systems [2]. Such an artificial interaction could be used to build advanced solid state simulators with non-Abelian character in a versatile cold-atom system.

[1] Y.-J. Lin, K. Jiménez-García, and I. B. Spielman, Nature (London) 471, 83-86 (2011).

[2] H. C. Koo et al., Science 325, 1515 (2009).

A 18.15 Tue 17:00 C/Foyer

Quench Dynamics of a Superfluid Fermi Gas in the BCS-BEC Crossover Regime — •Simon Hannibal[1], Peter Kettmann[1], Mihail Croitoru[2], Alexei Vagov[3], Vollrath Martin Axt[3], and Tilmann Kuhn[1] — [1]Institute of Solid State Theory, University of Münster — [2]Condensed Matter Theory, University of Antwerp — [3]Theoretical Physics III, University of Bayreuth

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

We calculate the dynamics of the BCS gap of a confined ultracold Fermi gas after a quantum quench, i.e., a sudden change of the coupling constant induced by switching the magnetic field. We show that the excitation induces an oscillation of the BCS gap which can be classified into the Higgs and Goldstone mode. Here we concentrate on the Higgs mode in the BCS-BEC crossover regime.

We find damped collective amplitude oscillations of the gap breaking down after a certain time. Afterwards rather irregular dynamics occur. The obtained frequencies are connected to the BCS gap and the size of the gas cloud. A linearization of the equations of motion is exploited to understand the origin of the observed behavior.

A 18.16 Tue 17:00 C/Foyer

Optimizing the production of RbCs ground-state molecules with high phase-space density — •Lukas Reichsöllner[1], Tetsu Takekoshi[1,2], Andreas Schindewolf[1], Silva Mezinska[1], Francesca Ferlaino[1,2], Rudolf Grimm[1,2], and Hanns-Christoph Nägerl[1] — [1]Institut für Experimentalphysik, Universität Innsbruck, Austria — [2]Institut für Quantenoptik und Quanteninformation IQOQI, Innsbruck, Austria

Ultracold dipolar systems are of high interest for quantum chemistry, precision spectroscopy, quantum many-body physics, and quantum simulation. Our goal is the production of dipolar RbCs rovibronic ground-state molecules with full control of all degrees of freedom and with high phase-space density. We first produce two spatially separated BECs of Rb and Cs. We use an optical lattice similar to the work in Ref. [1] to prevent three-body loss to create a Cs Mott insulator (MI) with single occupancy while having Rb spatially separated and superfluid (SF). We tune the interspecies interactions by using an interspecies Feshbach resonance and we move Rb on top of Cs with the aim to form a pair state with exactly one Rb and one Cs atom at each lattice site. Feshbach association and STIRAP transfer drive the Rb-Cs precursor pairs into the rovibronic ground-state. We present our work on the STIRAP ground-state transfer [2] and show data of the coexisting Rb SF and Cs MI phase in the same optical lattice as well as the Rb transport and merging of the two ultracold ensembles.

[1] J.G. Danzl et al., Nature Physics 6, 265 (2010) [2] T. Takekoshi et al., Phys. Rev. Lett. 113, 205301 (2014)

A 18.17 Tue 17:00 C/Foyer

Towards the Fermi Quantum Microscope — •Katharina Kleinlein[1], Ahmed Omran[1], Martin Boll[1], Timon Hilker[1], Guillaume Salomon[1], Immanuel Bloch[1,2], and Christian Gross[1] — [1]Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Straße 1, 85748 Garching, Germany — [2]Ludwig-Maximilians-Universität, Schellingstraße 4, 80799 München, Germany

Ultracold atoms in optical lattices have proven to be a powerful tool for exploring a variety of phenomena in strongly correlated many-body systems. Its controllability and possibilities of probing its states allow for simulation of a wide range of phenomena occurring in solid-state systems. A new door for exploring those many-body states opened with the achievement of single-site resolved imaging of bosonic atoms in optical lattices. However, single-site resolution of fermionic atoms remains challenging. Here we report on the latest progress of our ^{6}Li machine aimed at achieving this goal. We load ultracold ^{6}Li into a far detuned (1064nm) 3D optical lattice with variable lattice geometry. The system is described by the Fermi-Hubbard Hamiltonian, yielding a rich phase diagram for investigation. A smaller scale, deep pinning lattice is superimposed onto the larger scale physics lattice, where Raman-sideband cooling is applied. The scattered photons of this process provide the detection signal, which will be collected using a high resolution microscope objective. We present insights and progress on this Raman-sideband cooling and detection technique, representing a possible key technology towards single-site resolved imaging of strongly-correlated fermionic many-body systems.

A 18.18 Tue 17:00 C/Foyer

Polaronic effects in one- and two-band quantum systems — •Tao Yin, Daniel Cocks, Karla Baumann, and Walter Hofstetter — Institut für Theoretische Physik, Goethe-Universität, 60438 Frankfurt/Main, Germany

In this work we study the formation and dynamics of polarons in a system with a few latticed impurities immersed in a Bose-Einstein condensate (BEC). This system can be well described by a two-band model for the impurities, along with a Bogoliubov approximation for the BEC, with phonons coupled to impurities via both intra- and inter-band interaction. We decouple this Fröhlich-like coupling by an extended two-band Lang-Firsov polaron transformation using a variational method. The new effective Hamiltonian with two (polaron) bands differs from the original Hamiltonian by modified coherent transport, polaron energy shift and induced long-range interaction. Using Gutzwiller mean-field theory, we calculate the phase diagram and dynamics of this polaronic Hamiltonian in different dimension controlled by trapping lattice. An inhomogeneous system is also considered including BEC deformation from impurities, as well as a tilted optical lattice.

On the other hand, in order to focus on decoherence and relaxation effects, motivated by recent experiments, we specify our system as single impurity trapped in a quasi-1D system. Within a Lindblad master equation we take into account residual incoherent coupling between polaron and bath. Under this polaronic treatment, the inter-band relaxation process leads to a description of impurity dynamics beyond Fermi's Golden Rule.

A 18.19 Tue 17:00 C/Foyer

Experimental realization of the ionic Hubbard model on a honeycomb lattice with ultracold fermions — Michael Messer, •Rémi Desbuquois, Thomas Uehlinger, Gregor Jotzu, Frederik Görg, Daniel Greif, Sebastian Huber, and Tilman Esslinger — ETH Zurich, Zurich, Switzerland

Ultracold atoms in optical lattices constitute a tool of choice to realize the Fermi-Hubbard model. There, the on-site interaction energy opens a gap in the charge excitation spectrum, leading to a Mott insulating ground state. However, in the ionic Hubbard model, the addition of a staggered energy offset on each lattice site also leads to an insulating ground state with charge-density-wave ordering, even in the absence of inter-particle interactions. In our experiment we realize the Ionic Hubbard model on a honeycomb lattice by loading a two-component interacting Fermi gas into an optical lattice with a staggered energy offset on alternating sites. The underlying density order of the ground state is revealed through the correlations in the noise of the measured momentum distribution. For a large energy offset, we observe a charge-density-wave ordering, which is suppressed as the on-site interactions are increased. To further elucidate the nature of the ground state, we measure the double occupancy of lattice sites and the charge excitation spectrum for a wide range of parameters.

A 18.20 Tue 17:00 C/Foyer

Nonlinear tunneling in a Rydberg-dressed optical lattice — •Laura Gil and Thomas Pohl — Max-Planck-Institut für Physik komplexer Systeme, Dresden

We study ultra-cold atoms in an optical lattice that are off-resonantly excited to a high-lying Rydberg state. This Rydberg dressing is known to lead to tunable effective interactions between ground state atoms. However, we find that the motional dynamics of virtually excited Rydberg pairs also gives rise to interaction-induced tunnelling terms. In contrast to the common one-body tunnelling, these terms are of nonlinear and highly nonlocal nature. We discuss conditions for the most interesting case in which nonlocal interactions and tunnelling effects become comparable and explore its consequences for the resulting extended Bose-Hubbard model.

A 18.21 Tue 17:00 C/Foyer

Trapping of Topological Defects in Coulomb Crystals — •Philip Kiefer[1], Jonathan Brox[1], Ulrich Warring[1], Daniel Suess[2], Haggai Landa[3], David Gross[2], and Tobias Schaetz[1] — [1]Atom-, Molekül- und optische Physik, Physikalisches Institut, Universität Freiburg, Hermann-Herder-Str. 3, 79104 Freiburg — [2]Quantum correlations, Physikalisches Institut, Universität Freiburg, Rheinstr. 10, 79104 Freiburg — [3]LPTMS, Université Paris Sud, Orsay, France

We study structural defects (kinks) which are formed during the transition from a laser cooled cloud of Mg-Ions to a Coulomb crystal, consisting of more than 50 ions in a linear radiofrequency trap [1]. Simulations reveal a strong anharmonicity of the kink's internal mode of vibration, further enhanced bye the controlled extension into three dimensions. As a consequence, the periodic Peierls-Nabarro potential experienced by a discrete kink becomes a globally confining potential, capable of trapping defects at the center of the crystal.

The formation of kink configurations and the transformation of kinks between different structures in dependence on the trapping parameters are investigated. We present configurations of pairs of interacting kinks stable for long times [2], as well as a concept for fast detection and conditional manipulation.

[1] M. Mielenz et al., Phys. Rev. Lett. **110**, 133004 (2013)
[2] H. Landa et al., New J. Phys. **15**, 093003 (2013)

A 18.22 Tue 17:00 C/Foyer

Towards Sub-Doppler Cooling of Discrete Solitons inside Coulomb Crystals — •Jonathan Brox[1], Philip Kiefer[1], Haggai Landa[2], Ulrich Warring[1], and Tobias Schaetz[1] — [1]Atom-, Molekül- und optische Physik, Physikalisches Institut, Universität Freiburg, Hermann-Herder-Str. 3, 79104 Freiburg — [2]LPTMS, Université Paris Sud, Orsay, France

We study structural defects (kinks) which are formed during the transition from a laser cooled cloud of Mg-Ions to a Coulomb crystal [1]. Via tuning the ratio of the trapping frequencies we are able to shape the kink's structure [2]. Ion crystals with such structural defects feature a gapped mode in the spectrum of phonons. Since the gap separation of the latter is nearly independent of the crystal size, this approach could be particularly useful for producing entanglement and studying system-environment interactions in large, two- and possibly three-dimensional systems[3].

We discuss first concepts on the experimental realisation of subdoppler cooling based on two photon transitions in combination with topological defects.

[1] M. Mielenz et al., Phys. Rev. Lett. **110**, 133004 (2013)
[2] H. Landa et al., New J. Phys. **15**, 093003 (2013)
[3] H. Landa et al., Phys. Rev. Lett. **113**, 053001 (2014)

A 18.23 Tue 17:00 C/Foyer

Quantum Point Contacts for Strongly Interacting Fermions — •Sebastian Krinner, Dominik Husmann, Martin Lebrat, Charles Grenier, Jean-Philippe Brantut, and Tilman Esslinger — Institute for Quantum Electronics, ETH Zürich, 8093 Zürich, Switzerland

We extend the concepts of quantum simulation to device-like structures connected to atomic reservoirs. We use high-resolution microscopy to write tiny structures, such as a quantum point contact (QPC). The connected reservoirs allow us to measure transport in direct analogy to solid-state physics experiments, where transport measurements constitute an extremely sensitive tool to detect many-body effects. Here we study transport through a QPC in the normal, strongly interacting and superfluid regime. The system thereby goes smoothly from a regime exhibiting quantized conductance to a regime showing nonlinear I-V characteristics.

A 18.24 Tue 17:00 C/Foyer

Ba^+ and Rb laser system for ultracold chemistry experiments — •Georg Hoppe, Leon Karpa, Alexander Lambrecht, Julian Schmidt, and Tobias Schaetz — Albert-Ludwigs-Universität Freiburg

Our experimental setup is designed for the study of ultracold collisions [1] between Barium ions and Rubidium atoms in a BEC.

To reach the ultracold regime we first trap a Barium ion in a linear rf-Paul trap, where it's prepared and Doppler cooled to temperatures of millikelvin. We then transfer the ion into an optical trap [2] to avoid rf-induced heating effects [3]. As next step Rubidium atoms will be used to sympathetically cool the ion to reach the ultracold temperature regime.

I will present our laser systems for cooling and preparation of the ions and atoms. The most important among them are the lasers for Doppler cooling (493nm, 780nm), repumping (650nm) and photoionisation (413nm), which is stabilized with a cavity. Additionally, we designed a diode laser at 780nm [4] as a Rubidium imaging system.

[1] M. Krych et al., Phys. Rev. Lett. 83, 032723 (2011)
[2] T. Huber et al., Nat. Commun. 5 (2014)
[3] A.T. Grier et al., Phys. Rev. Lett. 102, 223201 (2009)
[4] L. Ricci et al., Optics Commun., 117 (1995)

A 18.25 Tue 17:00 C/Foyer

Unbalanced homodyne detection for interaction-free measurements — •Jan Peise[1], Bernd Lücke[1], Luca Pezzé[2], Frank Deuretzbacher[3], Wolfgang Ertmer[1], Jan Arlt[4], Augusto Smerzi[2], Luis Santos[3], and Carsten Klempt[1] — [1]Leibniz Universität Hannover, Welfengarten 1, 30167 Hannover, Germany — [2]Istituto Nazionale di Ottica (INO), Consiglio Nazionale delle Ricerche (CNR), and European Laboratory for Non-Linear Spectroscopy (LENS), 50125 Firenze, Italy — [3]Institut für Theoretische Physik, Leibniz Universität Hannover, Appelstraße 2, 30167 Hannover, Germany — [4]QUANTOP, Institut for Fysik og Astronomi, Aarhus Universitet, 8000 Arhus C, Denmark

Interaction-free measurements (IFMs) permit the detection of an object without the need of any interaction with it. Existing proposals for IFMs demand a single-particle source. Here, we realize a new many-particle IFM concept based on an indirect quantum Zeno effect in an unstable spinor Bose-Einstein condensate. For IFMs, it is necessary to discriminate between zero and a finite number of particles. We overcome this considerable experimental challenge by implementing an unbalanced homodyne detection for ultracold atoms. This new technique achieves single-particle sensitivity and serves as an important tool for future experiments in the field of quantum atom optics.

A 18.26 Tue 17:00 C/Foyer

Towards Ultracold Chemistry - Scattering of Ba+ and Rb in an optical dipole trap — •Alexander Lambrecht, Julian Schmidt, Georg Hoppe, Leon Karpa, and Tobias Schaetz — Albert-Ludwigs-Universitaet Freiburg

Examining collisions of atoms and ions at extremely low velocities permits to gain information about the corresponding scattering potentials and therefore of quantum effects in chemical reactions. In the last years several experimental groups investigated cold collisions between atoms and ions, leading to better understanding of the atom-ion interaction in many different aspects[1-3]. Our approach to reach the regime of ultracold collisions is to precool a barium+ ion, trapped in a conventional Radio-Frequency (RF) trap, by Doppler cooling followed by sympathetic cooling via an ambient rubidium MOT. By spatially overlapping the ion and the atom ensemble within a bichromatic optical dipole trap we overcome the limitations set by heating due to the RF micromotion[4]. We describe the experimental apparatus in its recent stage and the first experiments towards the simultaneous optical trapping of ions and atoms.

[1]A.T.Grier et al., Phys.Rev.Lett. 102,223201(2009)
[2]C.Zipkes et al., Nature 464, 388 (2010)
[3]W.G.Rellergert et al. , Phys.Ref.Lett. 107,243201 (2011)
[4]T.Huber et al., Nat. Comm. 5, 5587 (2014)

A 18.27 Tue 17:00 C/Foyer

Single Atom Detection in Ultracold Quantum Gases — •Carola Rogulj, Tobias Menold, Malte Reinschmidt, Peter Federsel, Markus Stecker, Hannah Schefzyk, Andreas Günther, and József Fortágh — Physikalisches Institut, Universität Tübingen, Germany

Investigating quantum gases beyond the mean field approach, has become one of the main research topics in quantum-atom optics. Therefore, single atom detection techniques have to be developed, which allow for measuring statistics and correlations in ultracold quantum gases.

Our approach uses a state- and energy-selective ionization scheme, to realize a time-resolved single atom detector. We demonstrate the performance of this detector, by measuring dynamical processes, like center-of mass oscillations or shape oscillations, in real-time with high detection efficiency. This way, we demonstrate force spectroscopy and measure the energy distribution of trapped quantum gases in-situ. Having access to temporal correlations, we realize noise-spectroscopy on ultracold quantum gases, which proof the detection scheme to be suitable for realizing quantum galvanometer [1].

To extend the single atom detection to the spatial regime, we develop a novel high resolution ion microscope, which allows for magnifications up to 1000 and spatial resolution below the optical diffraction limit. We present both, the simulations and the first experimental realization of such a time- and space-resolved single atom detector.

[1] Kalman et al., Nano Letters 12, 435-439 (2012)

A 18.28 Tue 17:00 C/Foyer

High efficiency demagnetization cooling by suppression of light-assisted collisions — •Jahn Rührig, Tobias Bäuerle, Axel Griesmaier, and Tilman Pfau — 5. Physikalisches Institut, Universität Stuttgart, Pfaffenwaldring 57, Stuttgart, 70569 , Germany

Demagnetization cooling [1] utilizes dipolar relaxations [2] that couple the internal degree of freedom (spin) to the external (angular momentum) in order to cool an atomic cloud efficiently [3,4]. Optical pumping into a dark state constantly recycles the atoms that were promoted to higher spin states. The net energy taken away by a single photon is very favorable since the lost energy per atom is the Zeeman energy rather than the recoil energy. As the density of the atomic sample rises the inherent involvement of the photons leads to limiting processes. In our previous publication [5] we have shown that light-assisted collisions are such an important limiting process. We present latest results on the suppression of light-assisted collisions in ^{52}Cr by detuning the optical pumping light such that the Condon point coincides with the first node of the ground state wave function of two colliding atoms [6]. This leads to an increased cooling efficiency $\chi \geq 17$ as well as to increased maximum densities of $n \approx 1 \cdot 10^{20} m^{-3}$.

[1]:A. Kastler, Le Journal de Physique et le Radium 11, 255 (1950).
[2]:S. Hensler et al. , Appl.Phys.B 77, 765 (2003).
[3]:S. Hensler et al. , Europhys. Lett. 71,918 (2005).
[4]:M. Fattori et al. , Nature Physics 2, 765 (2006).
[5]:V. Volchkov et al. , Phys. Rev. A 89, 043417 (2014).
[6]: K. Burnett et al. , Phys. Rev. Lett. 77, 1416-1419 (1996).

A 18.29 Tue 17:00 C/Foyer

Cold atoms near superconductors: Towards coherent coupling in a hybrid quantum system — •Helge Hattermann, Lörinc Sárkány, Patrizia Weiss, Daniel Bothner, Matthias Rudolph, Benedikt Ferdinand, Simon Bernon, Reinhold Kleiner, Dieter Koelle, and József Fortágh — CQ Center for Collective Quantum Phenomena and their Applications, Physikalisches Institut Tübingen, Auf der Morgenstelle 14, 72076 Tübingen

We describe an experimental system combining Bose-Einstein condensates and superconducting atom chips at 4.2 K. We demonstrate the coherent state manipulation of atoms at the superconducting chip [1], the generation of noise protected clock states [2] and the design and implementation of superconducting coplanar waveguide cavities. In addition, we present experimental results on the mapping of the flux state in a superconducting ring onto an ensemble of cold atoms.

[1] S. Bernon *et. al.*, Nat. Commun. **4**, 2380 (2013)
[2] L. Sárkány *et. al.*, Phys. Rev. A **90**, 053416 (2014)

A 18.30 Tue 17:00 C/Foyer

Interference of ultracold Bose gases — •Holger Hauptmann, Sigmund Heller, and Walter T. Strunz — Technische Universität Dresden

We study equilibrium and dynamical aspects of ultracold quasi one-dimensional Bose gases with repulsive self interaction. To describe Bose gases in the canonical ensemble (fixed particle number) a non-linear stochastic matter-field equation will be presented. Applications of this equation to interference experiments from the Schmiedmayer group [1] will be shown. Moreover to study dynamical properties, it is necessary to create two correlated quasi one-dimensional cigar-shaped Bose gases. We present a stochastic splitting mechanism which simulates the tearing of one quasi one-dimensional cigar-shaped gas along the logitudinal axis into two Bose gases. Applications to dynamical interference experiments [1] exhibit good agreement.

A 18.31 Tue 17:00 C/Foyer

Toward cold atom mixture of lithium and caesium — •Pierre Jouve — University of Nottingham, United Kingdom

Ultracold mixtures hold the promise of understanding new phases of matter and collisions at very low energies. We are setting up an experiment for bose-fermi mixtures of lithium and caesium, which are especially well suited to study impurities, transport, solitons or mixtures in optical lattices. These species are appealing because they offer favourable interactions properties and can be manipulated independently of each other due to their different resonance frequencies. Here we present the current status of our experiment. We detail the cooling schemes for the two atomic species and include the development and optimal loading of an optical dipole trap. We have constructed a two-species Zeeman slower for subsequent loading of lithium and caesium. We are also investigating ways to couple cold and ultracold caesium atoms to photons delivered through a waveguide. In principle such a light-matter interface can act as a building block for photon storage, optical switching or quantum computational tasks [1]. This work is funded by an EU-FET- young explorers project and includes researchers from the University of Vienna, Dresden, Jena and Nottingham.

A 18.32 Tue 17:00 C/Foyer

Phase-Imprinting through Rydberg Dressing — Rick Mukherjee[1], Cenap Ates[2], Weibin Li[2], and •Sebastian Wüster[1] — [1]Max Planck Institute for the Physics of Complex Systems, Nöthnitzer Strasse 38, 01187 Dresden, German — [2]School of Physics and Astronomy, University of Nottingham, Nottingham, NG7 2RD, UK

We show how the phase profile of Bose-Einstein condensates can be engineered through its interactions with suitably placed Rydberg excitations. The interaction is made controllable and long-range by off-resonantly coupling the condensate to another Rydberg state as in [1], which will dominate over direct interactions between condensate atoms and Rydberg electrons [2].

Our technique allows the mapping of entanglement generated in systems of few strongly interacting Rydberg atoms onto much larger atom clouds in hybrid setups. As an example we discuss the creation of a spatial mesoscopic superposition state from a bright soliton. Additionally, the phase imprinted onto the condensate using the Rydberg excitations can be used to infer the locations of the latter. We investigate the resulting link between condensate momentum distributions and different embedded Rydberg crystal patterns.

[1] N. Henkel *et al.* Phys. Rev. Lett. **104**, 195302 (2010).
[2] J. B. Balewski *et al.* Nature **502**, 664 (2013)

A 18.33 Tue 17:00 C/Foyer

Single shot realization and characterization of multiple quantum phase transitions — •Robert Heck, Romain Müller, Aske R. Thorsen, Mario Napolitano, Mark G. Bason, Jan Arlt, and Jacob F. Sherson — Department of Physics and Astronomy, Aarhus University, Ny Munkegade 120, 8000 Aarhus C, Denmark

Local manipulation of ultracold atomic clouds with optically induced micropotentials has in recent years become a versatile tool. Among others, they have been used for efficient BEC creation using the so-called dimple approach [1, 2], to form arbitrarily shaped traps [3], and recently to address single atoms in an optical lattice [4].

We present our setup for creating time-averaged potentials with a strongly focused laser beam. In analogy with previous work [2], we have demonstrated up to 30 consecutive, conservative crossings of the phase transition to a BEC. Here, however, we combine the approach with high-resolved QND imaging to enable the continuous characterization of the dynamics. This allows us to investigate online the evolution of the in-situ cloud across the transition. Next steps will be the single-shot detection of entire phase diagrams and investigations of the stochastic nature of condensation dynamics during the formation of a BEC.

Finally, our setup allows for the simultaneous loading of several micro traps. The coherence properties of these has been verified by the observation of interference in ballistic expansion.

[1] P. Pinkse et al., PRL **78**, 990 (1997); [2] D. Stamper-Kurn et al., PRL **81**, 2194 (1998); [3] K. Henderson et al., NJP **11**, 043030 (2009); [4] C. Weitenberg et al., Nature **471**, 319 (2011)

A 18.34 Tue 17:00 C/Foyer

Linear to zigzag transition in dipolar chains — •Florian Cartarius[1,2,3], Anna Minguzzi[2,3], and Giovanna Morigi[1] — [1]Theoretische Physik, Universität des Saarlandes, 66123 Saarbrücken, Germany — [2]Laboratoire de Physique et Modélisation des Milieux Condensés, Université Grenoble Alpes, F-38000 Grenoble, France — [3]Laboratoire de Physique et Modélisation des Milieux Condensés, CNRS, F-38000 Grenoble, France

In very anisotropic confinement cold dipolar particles can arrange in linear chains. By relaxing the transverse confinement these chains split into a zigzag structure. We consider a chain of dipolar bosons superimposed by an optical lattice, where the particles can tunnel from one site to the next. In deep optical lattices the coupling to the axial phonons can be neglected and it is possible to describe the behaviour of the system by two coupled extended Bose-Hubbard Hamiltonians close to the transition [1]. We present the solution of this model using a path integral Monte Carlo method.

[1] Pietro Silvi, Tommaso Calarco, Giovanna Morigi, Simone Montangero, Phys. Rev. B 89, 094103 (2014)

A 18.35 Tue 17:00 C/Foyer

Towards Nanofiber-Based Quantum Networks — •Jakob Hinney, Christoph Clausen, Adarsh Prasad, Philipp Schneeweiss, Jürgen Volz, and Arno Rauschenbeutel — VCQ, TU Wien, Atominstitut, Stadionallee 2, 1020 Wien, Austria

In a new project, we plan to establish nanofiber-based atom-light interfaces as quantum-enabled fiber-optical components for quantum in- formation processing and communication. The key ingredient is a nanofiber-based optical dipole trap which stores cold atoms in the evanescent field around the nanofiber [1,2]. In this evanescently coupled atom-waveguide-system, even a few hundred atoms are already optically dense for near-resonant photons propagating through the nanofiber. The first goal of this project is to realize efficient quantum memories which allow one to directly store and retrieve the quantum state of fiber-guided photons. Furthermore, nanofiber-coupled atoms can provide a strong optical non-linearity. The second goal of this project is to explore and to maximize this non-linearity until it prevails down to the single photon level. This would then enable optical quantum switches and photon-photon quantum gates which are essential for implementing deterministic optical quantum computation. The final goal is to interconnect these components in order to demonstrate different quantum network applications, such as highly efficient photon counting, heralded entanglement of two fiber-coupled quantum memories, and a non-linear interaction between two single-photon pulses.

[1] E. Vetsch et al., Phys. Rev. Lett. 104, 203603 (2010). [2] D. Reitz et al., Phys. Rev. Lett. 110, 243603 (2013).