Q 32: Poster: Quantum gases, ultracold atoms and molecules

Time: Wednesday 16:30–18:30 Location: Spree-Palais

Q 32.1 Wed 16:30 Spree-Palais

Driven-dissipative two-dimensional Bose-Einstein condensation — EHUD ALTMAN[1], JOHN TONER[2], •LUKAS M. SIEBERER[3,4], SEBASTIAN DIEHL[3,4], and LEIMING CHEN[5] — [1]Department of Condensed Matter Physics, Weizmann Institute of Science, Rehovot 76100, Israel — [2]Department of Physics and Institute of Theoretical Science, University of Oregon, Eugene OR, 97403, U.S.A. — [3]Institute for Theoretical Physics, University of Innsbruck, A-6020 Innsbruck, Austria — [4]Institute for Quantum Optics and Quantum Information of the Austrian Academy of Sciences, A-6020 Innsbruck — [5]College of Science, The China University of Mining and Technology, Xuzhou Jiangsu, 221116, P.R. China

The non-equilibrium dynamics of driven-dissipative Bose condensates is described by the dissipative stochastic Gross-Pitaevskii equation, which in the long-wavelength limit can be mapped exactly to the Kardar-Parisi-Zhang equation. This mapping allows us to show that for two-dimensional isotropic systems deviations from equilibrium are relevant perturbations in the renormalization group sense, leading ultimately to the destruction of the condensate at the longest scales. This is in stark contrast to the three-dimensional case where thermodynamic properties and long range correlations mimic the behavior of equilibrium systems with truly non-equilibrium phenomena arising in the dynamics only. Effective equilibrium can be established in two-dimensional driven-dissipative condensates only if rotational symmetry is strongly broken. Then the transition to the disordered phase occurs by a standard equilibrium Kosterlitz-Thouless transition.

Q 32.2 Wed 16:30 Spree-Palais

Non-Equilibrium Heating Dynamics of a Luttinger Liquid — •MICHAEL BUCHHOLD[1] and SEBASTIAN DIEHL[1,2] — [1]Institute for Theoretical Physics, University of Innsbruck, A-6020 Innsbruck, Austria — [2]Institute for Quantum Optics and Quantum Information of the Austrian Academy of Sciences, A-6020 Innsbruck, Austria

Recent studies of heating and thermalization of interacting one-dimensional (1D) bosons in cold atom experiments have triggered the interest in the non-equilibrium dynamics of low dimensional bosons. In a non-equilibrium Keldysh path integral approach for Luttinger Liquids, we investigate a 1D Bose gas subject to permanent heating.

We determine the non-equilibrium phonon distribution, thereby distinguishing the short distance dynamics, essentially revealing thermal behavior, from the universal non-equilibrium long wavelength dynamics of the system.

The universal behavior is encoded in the exponents of the dissipative phonon decay and leads to modifications of physical observables compared to thermal equilibrium. We demonstrate the effect of heating on relevant experimental signatures, such as the dynamical structure factor or the density of states and show how thermalization processes and universality can be traced from these observables.

Q 32.3 Wed 16:30 Spree-Palais

Collision studies in ultra cold calcium atoms — •HANNES WINTER and ANDREAS HEMMERICH — Institut für Laserphysik, Universität Hamburg,

We present collision studies of metastable optically trapped calcium atoms and discuss the feasibility of achieving Bose-Einstein condensation in these states by evaporative cooling methods. The metastable states of alkaline earth and rare earth elements have novel elastic and inelastic scattering properties [1], with important implications for applications like time metrology and lattice-based quantum computing.

The atoms are prepared by an alternative method analogous to the one used to create a ground state BEC [2].

We also discuss our new setup to realize a superradiant laser [3] similar to the proposal by [4].

[1] V. Kokoouline *et al.*, Phys. Rev. Lett. **90**, 253201 (2003).

[2] P. Halder, C.-Y. Yang and A. Hemmerich, Phys. Rev. A **85**, 031603 (2012).

[3] M. Holland and J. Thompson *et al.* Nature, **484**(7392):78-81, (2012).

[4] M. Holland *et al.*, Phys. Rev. Lett. **102**(16):163601, (2009).

Q 32.4 Wed 16:30 Spree-Palais

Non-thermal fixed points and strong wave-turbulence in a dilute Bose gas — •ISARA CHANTESANA[1,2] and THOMAS GASENZER[1,2] — [1]Institut für Theoretische Physik, Ruprecht-Karls-Universität Heidelberg, Philosophenweg 16, 69120 Heidelberg, Germany — [2]ExtreMe Matter Institute EMMI, GSI Helmholtzzentrum für Schwerionenforschung GmbH, Planckstraße 1, 64291 Darmstadt, Germany

Far-from equilibrium dynamics of a dilute Bose gas is studied by means of the two-particle irreducible action formalism. We investigate the properties of non-thermal fixed points predicted previously, which are related to non-perturbative strong wave turbulence solutions of the many-body dynamic equations. According to these predictions, the occupation number spectrum shows two alternative new scaling laws in the low-momentum regime, as a consequence of a non-perturbative scaling of the coupling parameter caused by many-body effects. We study this scaling in view of integrability constraints in order to clarify whether the non-thermal fixed point has Gaussian character. This question is of central interest for the development of a renormalisation-group description of far-from-equilibrium critical phenomena.

Q 32.5 Wed 16:30 Spree-Palais

Crossover from Adiabatic to Sudden Quench Dynamics for Time-of-Flight Imaging Measurements in Bose-Einstein Condensates — BO XIONG[1], AXEL PELSTER[2], and •ANTUN BALAŽ[1] — [1]Scientific Computing Laboratory, Institute of Physics Belgrade, University of Belgrade, Serbia — [2]Physics Department and Research Center OPTIMAS, Technische Universität Kaiserslautern, Germany

Time-of-flight imagining is one of the standard techniques used in experiments with Bose-Einstein condensates (BECs) to measure and study their physical properties. Here we investigate effects of a controlled time-dependent quench of a trapping potential on Time-of-Flight (TOF) images in one-component (^{87}Rb) and two-component (a mixture of ^{87}Rb and ^{39}K) condensates. To this end we model the following experimental protocol: initially the condensate is in the ground state and then the frequencies of a cylindrically-symmetric harmonic trapping potential are quenched during a given time interval T. This will generate a BEC dynamics within the intriguing crossover from adiabatic to sudden quench dynamics, which affects the TOF images made immediately afterwards. We study both numerically and variationally such effects of quenching of a trapping potential, as well as necessary modifications to the algorithm used for reconstructing the density profile of a BEC cloud. The obtained results are relevant for new experiments, which are performed e.g. at the Center of Applied Space Technology and Microgravity (ZARM) at the University of Bremen [1] and offer a glimpse into the non-equilibrium BEC physics.

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

Q 32.6 Wed 16:30 Spree-Palais

Bose-Einstein Condensate in Gravitational Cavity: Comparing Soft and Hard Wall Boundary Condition — •JAVED AKRAM[1] and AXEL PELSTER[2] — [1]Department of Physics, Freie Universität Berlin, Germany — [2]Fachbereich Physik und Forschungszentrum OPTIMAS, Technische Universität Kaiserslautern, Germany

Within a one-dimensional gravitational cavity the effect of gravity is compensated by an exponentially decaying potential, which is created by the total internal reflection of an incident laser beam from the surface of a dielectric serving as a mirror for the atoms. We describe a weakly interacting Bose-Einstein condensates (BEC) in such a one-dimensional gravitational cavity with different trial mean-field condensate wave functions, where both its width and its height are considered as variational parameters. In particular, we determine the variational results for the BEC equilibrium configuration when the surface is modelled by a soft or a hard wall boundary condition. By considering small deflections around the respective equilibrium positions, we also investigate the collective excitations of the BEC. Furthermore, we analyze how the BEC cloud expands ballistically due to gravity after switching off the evanescent laser field.

Q 32.7 Wed 16:30 Spree-Palais

Doublons and Holons in perodically driven Mott insulators — •MAXIMILIAN GENSKE and ACHIM ROSCH — Institut für Theoretische Physik, Universität zu Köln, D-50937 Cologne, Germany

Periodically driven systems can lead to a directed motion of particles. We investigate this ratchet effect for a bosonic Mott insulator where both a staggered hopping and a staggered local potential vary periodically in time. If driving frequencies are smaller than the interaction strength and the density of excitations is small, one obtains effectively a one-particle quantum ratchet describing the motion of doubly occupied sites (doublons) and empty sites (holons). Such a simple quantum machine can be used to manipulate the excitations of the Mott insulator. For suitably chosen parameters, for example, holons and doublons move in opposite direction. To investigate whether the periodic driving can be used to move particles "uphill", i.e., against an external force, we study the influence of a linear potential $-Fx$. For long times, transport is only possible when the driving frequency ω and the external force F are commensurate, $nF = m\omega$, with $n, m \in \mathcal{Z}$.

Q 32.8 Wed 16:30 Spree-Palais

Analytic study of the expansion dynamics of multi-species Bose-Einstein condensates — •Matthias Meister, Albert Roura, Wolfgang P. Schleich, and the QUANTUS Team — Institut für Quantenphysik, Universität Ulm

Quantum tests of the weak equivalence principle can be performed by comparing the free fall of different species of ultra-cold quantum gases via differential interferometry measurements. Hence, it is essential to have a theoretical model for such mixtures.

Starting from the ground-state solution in the Thomas-Fermi approximation, we provide an efficient analytical description of the expansion dynamics of a multi-species mixture of Bose-Einstein condensates (BECs). For this purpose we generalize the scaling approach developed for a single-species BEC [1] to the case of multiple species. We show that this technique is possible as long as the trapping frequencies are identical for all species. Thus, this formulation constitutes a good approximation for mixtures of different isotopes of a heavy element (e. g. ^{85}Rb and ^{87}Rb) confined by the same trapping potential.

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

[1] Y. Castin and R. Dum, Phys. Rev. Lett. **77**, 5315 (1996).

Q 32.9 Wed 16:30 Spree-Palais

Quantum dynamics in ultracold environments — •Paula Ostmann and Walter Strunz — TU Dresden, Institut für Theoretische Physik, Dresden, Deutschland

We investigate quantum dynamics of particles (molecules, ions) in ultracold quantum environments. Examples we have in mind are molecules immersed in a helium nanodroplet, or ions immersed in an ultracold atomic gas. The ultracold environment acts as a refrigerator, and thus, the influence on the motion of the molecule or ion is dissipative. For a theoretical description, simple phenomenological master equation approaches are widely used to describe the ensuing damped quantum dynamics.

In our contribution the focus lies on a more detailed description of the environment and the particle-environment interaction. We aim to describe the effective dynamics of the damped particle dynamics using the full bath correlation function instead of a simple damping rate. In this way we gain a more thorough theoretical understanding of properties of quantum matter, such as superfluidity, when acting as an environment.

Q 32.10 Wed 16:30 Spree-Palais

Generalized Bose condensation into multiple states and heat transport in tight-binding lattices far from equilibrium — •Alexander Schnell[1,2], Daniel Vorberg[1,2], Waltraut Wustmann[1,2], Roland Ketzmerick[1,2], and André Eckardt[1] — [1]Max-Planck-Institut für Physik komplexer Systeme, Nöthnitzer Str. 38, 01187 Dresden, Germany — [2]Technische Universität Dresden, Institut für Theoretische Physik, 01062 Dresden, Germany

If an ideal Bose gas is driven into a steady state far from equilibrium, then a generalized form of Bose condensation can occur [1]. Namely the single-particle states unambiguously separate into two groups: one, that we call Bose selected, whose occupations increase linearly when the total particle number is increased at *fixed system size, and another one whose occupations saturate. We study this effect in a tight-binding lattice, where the non-equilibrium regime is achieved either by coupling the system to two heat baths, one of positive and another one of negative temperature, or by a combination of periodic forcing and the coupling to a heat bath. We investigate which and how many single-particle states are selected in such lattice systems. We, moreover, address how system properties like the heat conductivity are controlled by the various parameters of the model, like lattice size, dimensionality, or the coupling to the heat bath(s).

[1] D. Vorberg, W. Wustmann, R. Ketzmerick and A. Eckardt, Phys. Rev. Lett. (to be published), arXiv:1308.2776

Q 32.11 Wed 16:30 Spree-Palais

Single atom detection in ultracold quantum gases — •Peter Federsel, Hannah Schefzyk, Markus Stecker, Malte Reinschmidt, Andreas Günther, and József Fortágh — Physikalisches Institut, Universität Tübingen, Germany

We develop experimental techniques based on single atom detection, for monitoring the dynamics of ultracold atomic clouds and Bose-Einstein condensates in real time. At present, we investigate photoionization in focussed laser beams and field ionization at nanosized, charged metallic tips. Using a channel electron multiplier, the produced ions are detected with single particle sensitivity and high temporal resolution. Both schemes allow for fast, local probing and feedback on the cloud dynamics. The method is demonstrated by reconstructing the trapping potential from the cloud's oscillation behavior (dynamic force spectroscopy).

The development of a novel high resolution ion microscope will extend the detection scheme to allow for spatial detection below the optical diffraction limit. This opens up the possibility for future temporal and spatial correlation measurements on ultracold quantum gases.

Q 32.12 Wed 16:30 Spree-Palais

Wave packet dynamics of a Bose Einstein Condensate in a one dimensional, disordered potential for variable interaction strengths — •Juan Pablo Ramírez Valdes, Thomas Wellens, and Andreas Buchleitner — Physikalisches Institut, Albert-Ludwigs Universität Freiburg, Herman-Herder-Str. 3a, 79104 Freiburg, Germany

We study the impact of interactions on the wave packet dynamics of Bose Einstein condensates (BEC) in a one dimensional, disordered potential, with particular focus on the comparison between the regimes of localized and diffusive transport. In a first step, we develop a numerical method to effciently solve the time-dependent Gross-Pitaevskii equation (GPE) for Gauss-correlated disorder, and monitor the wave packet dynamics as a function of increasing interaction strength.

Q 32.13 Wed 16:30 Spree-Palais

Free Falling Bose Einstein Condensates in General Relativity — •Oliver Gabel and Reinhold Walser — Institut für Angewandte Physik, Technische Universität Darmstadt, Hochschulstr. 4a, 64289 Darmstadt

The recent development of matter-wave interferometry into a new tool for precision metrology holds the potential for measuring general relativistic effects to high accuracy.

The demonstration of Bose-Einstein condensates (BECs) and matter wave interferometers in free fall by the QUANTUS collaboration [1,2] is at the forefront of this endeavour and aims at the verification of Einstein's equivalence principle, the foundation of general relativity.

In this context, it has become relevant to extend the usual Newtonian description of BECs [3] to general relativity and to study the arising corrections in a systematic way. In this contribution, we present our latest results on the description of free falling BECs in curved spacetime, based on the non-linear covariant Klein-Gordon equation and a local expansion of the metric tensor of the background space-time in terms of Fermi normal coordinates.

[1] T. van Zoest et. al., *Bose-Einstein Condensation in Microgravity*, Science, **328**, 1540 (2010).
[2] H. Müntinga et. al., *Interferometry with Bose-Einstein Condensates in Microgravity*, Phys. Rev. Lett. **110**, 093602 (2013).
[3] G. Nandi, R. Walser, E. Kajari, and W. P. Schleich, *Dropping cold quantum gases on Earth over long times and large distances*, Phys. Rev. A **76**, 63617 (2007).

Q 32.14 Wed 16:30 Spree-Palais

Nonthermal Fixed Points and Superfluid Turbulence in Ultracold Bose Gases — Sebastian Erne[1,2], •Markus Karl[1,2], Steven Mathey[1,2], Boris Nowak[1,2], Andreas Samberg[1,2], Jan Schole[1,2], Carlo Ewerz[1,2], and Thomas Gasenzer[1,2] — [1]Institut für Theoretische Physik, Ruprecht-Karls-Universität Heidelberg, Philosophenweg 16, 69120 Heidelberg — [2]ExtreMe Matter Institute EMMI, GSI Helmholtzzentrum für Schwerionenforschung GmbH, Planckstraße 1, 64291 Darmstadt, Germany

Turbulence appears in situations where, e.g., an energy flux goes from large to small scales where finally the energy is dissipated. As a result the distribution of occupation numbers of excitations follows a power law with a universal critical exponent. The situation can be described as a nonthermal fixed point of the dynamical equations. Single-particle momentum spectra for a dynamically evolving Bose gas are analysed using semi-classical simulations and quantum-field theoretic methods based on effective-action techniques. These give information about possible universal scaling behaviour. The connection of this scaling with the appearance of topological excitations such as solitons and vortices in one-component gases and domain walls and spin textures in multi-component systems is discussed. In addition, this results are also discussed from the point of view of holographic superfluids. The results open a view on solitary wave dynamics from the point of view of critical phenomena far from thermal equilibrium and on a possibility to study non-thermal fixed points and superfluid turbulence in experiment without the necessity of detecting solitons and vortices in situ.

Q 32.15 Wed 16:30 Spree-Palais

Solitonic states far from equilibrium — •Sebastian Erne[1,2,3], Robert Bücker[3], Boris Nowak[1,2], Thomas Gasenzer[1,2], and Jörg Schmiedmayer[3] — [1]Institut für Theoretische Physik, Ruprecht-Karls-Universität Heidelberg, Philosophenweg 16, 69120 Heidelberg — [2]ExtreMe Matter Institute EMMI, GSI Helmholtzzentrum für Schwerionenforschung GmbH, Planckstraße 1, 64291 Darmstadt, Germany — [3]Vienna Center for Quantum Science and Technology (VCQ), Atominstitut, TU Wien, Vienna, Austria

We study the dynamics of solitonic excitations in a finite size ultracold Bose gas out of equilibrium in one spatial dimension and propose an interpretation of this state in terms of turbulence. Nontrivial finite size effects are found in the momentum distribution, in the form of characteristic multi-peak structures. We analytically describe the state within a model of randomly distributed solitons and address the possibilities for an experimental observation of the solitonic state via statistical simulations using the classical field equations. Further the creation and dynamics of solitonic defects are addressed in a variety of setups, including rapid cooling, dissipative effects and quenching the chemical potential of the system. The results give detailed insight into the effects of solitonic excitations for experiments of a rapid cooling quench performed by R. Bücker *et al.* at the Atominstitut in Vienna.

Q 32.16 Wed 16:30 Spree-Palais

Study of doublon dynamics in the Bose-Hubbard model using low-energy theories — •Holger Niehus and Daniela Pfannkuche — I. Institut für Theoretische Physik, Universität Hamburg, 20355 Hamburg, Deutschland

Identifying the relevant processes for the dynamics of excitations far from equilibrium is one of the most challenging tasks in many particle physics. We approach this problem for a special class of excited states in the Bose-Hubbard model, so-called doublons, by means of effective low-energy models in conjunction with exact diagonalization. For large on-site interaction U, doublons can not decay directly. The existence of a finite bandwidth and energy conservation prohibits the conversion of the interaction-energy of the two constituent particles to kinetic energy.

We study the interaction of few doublons by creating two doubly occupied sites in an otherwise empty lattice. The low-energy theory of third order in the hopping is recast to a doublon-doublon Hamiltonian capturing the essential dynamics. We further investigate the applicability of this model for many doublons and show in which cases the model may break down.

Complementary we study the influence of neighboring bosons on the dynamics of a single doublon. We show that the dynamics of such systems may be described by a doublon-holon model.

Q 32.17 Wed 16:30 Spree-Palais

Dynamics of Dark and Dark-Bright Solitons beyond the Mean-Field Approximation — •Sven Krönke[1] and Peter Schmelcher[1,2] — [1]Center for Optical Quantum Technologies, University of Hamburg, Luruper Chaussee 149 , 22761 Hamburg , Germany — [2]The Hamburg Centre for Ultrafast Imaging, University of Hamburg, Luruper Chaussee 149 , 22761 Hamburg , Germany

Dark solitons are well-known excitations in one-dimensional repulsively interacting Bose-Einstein condensates, which feature a characteristical phase-jump across a density dip and formstability in the course of their dynamics. While these objects are stable within the celebrated Gross-Pitaevskii mean-field theory, the situation changes dramatically in the full many-body description: The condensate being initially in a dark soliton state dynamically depletes and the density notch fills up with depleted atoms. We analyze this process in detail with a particular focus on two-body correlations and the fate of grey solitons (dark solitons with finite density in the notch) and thereby complement the existing results in the literature. Moreover, we extend these studies to mixtures of two repulsively interacting bosonic species with a dark-bright soliton (dark soliton in one component filled with localized atoms of the other component) as the initial state. All these many-body quantum dynamics simulations are carried out with the recently developed multi-layer multi-configuration time-dependent Hartree method for bosons (ML-MCTDHB).

Q 32.18 Wed 16:30 Spree-Palais

Experimental apparatus for long-range interacting potassium-40 quantum gases — •Silva Mezinska, Stephan Helmrich, Alexander Sayer, Christoph Hofmann, Valentin Ivannikov, and Shannon Whitlock — Physikalisches Institut, Universität Heidelberg, Germany

We present a new experimental apparatus aimed at studying strongly correlated phases of ultracold quantum gases in low-dimensional geometries. By tailoring the interactions between ultracold atoms in optical traps we aim to create new states of matter and shed new light on many-body quantum effects beyond what has been possible in traditional condensed-matter and cold-atom systems.

The experimental setup consists of an ultrahigh-vacuum chamber, which includes an electrode structure for controlling electric fields and integrated optics for single-atom sensitive imaging. We will trap potassium-40 atoms in an optical dipole trap, loaded by 2D and 3D magneto-optical traps. To introduce long-range interactions between the atoms we plan to weakly admix Rydberg-state character via laser coupling ('Rydberg-dressing'). Our main goal is to understand the role of quantum correlations on new phases of matter involving coupled 1D and 2D systems of fermions (bilayer and biwire systems). Ultimately, these experiments will provide the foundation to explore the full quantum phase structure of strongly-correlated quantum systems with long-range interactions.

Q 32.19 Wed 16:30 Spree-Palais

Quantum magnetism without lattices in strongly-interacting one-dimensional spinor gases — •Frank Deuretzbacher[1], Daniel Becker[2], Johannes Bjerlin[3], Stephanie Reimann[3], and Luis Santos[1] — [1]Institute for Theoretical Physics, Leibniz University Hanover, Appelstr. 2, DE-30167 Hanover, Germany — [2]Department of Physics, University of Basel, Klingelbergstrasse 82, CH-4056 Basel, Switzerland — [3]Mathematical Physics, LTH, Lund University, SE-22100 Lund, Sweden

We show that strongly-interacting multicomponent gases in one dimension can be described by an effective spin model. This constitutes a surprisingly simple scenario for the realization of one-dimensional quantum magnetism in cold gases in the absence of an optical lattice. The spin-chain model allows for an intuitive understanding of recent experiments and for a simple calculation of relevant observables. We analyze the adiabatic preparation of antiferromagnetic and ferromagnetic ground states, and show that many-body spin states may be efficiently probed by means of tunneling experiments. The spin-chain model is valid for more than two components, opening the possibility of realizing SU(N) quantum magnetism in strongly-interacting one-dimensional alkaline-earth or Ytterbium Fermi gases.

Q 32.20 Wed 16:30 Spree-Palais

The critical velocity in the BEC-BCS crossover — •Niclas Luick, Kai Morgener, Wolf Weimer, Jonas Siegl, Klaus Hueck, and Henning Moritz — Institut für Laserphysik, Universität Hamburg, D-22761 Hamburg

Ultracold fermionic gases are an ideal model system for the study of quantum many-body phenomena. Of particular interest is superfluidity due to the open questions surrounding high-temperature superconductors in solids. One hallmark property of superfluid systems is the critical velocity below which obstacles can move through the fluid without friction.

The broad Feshbach resonance of fermionic 6Li quantum gases provides the unique possibility to investigate superfluidity over a wide range of interactions. We stir the gas with a red-detuned laser beam as a local density perturbation. Above the critical velocity heating can be observed. We present high-precision measurements of the critical velocity along the BEC-BCS crossover which are in excellent agreement with theoretical predictions. The three-dimensional gas can also be transferred to a single layer of a blue-detuned one-dimensional optical lattice. This opens the opportunity to study superfluidity in two-dimensional systems with interactions very different from the three-dimensional case. The actual state of our measurements as well as an overview of our apparatus will be presented.

Q 32.21 Wed 16:30 Spree-Palais

Towards quantum simulation with strongly correlated Fermi gases — •Andrea Morales[1,2], A. Burchianti[2], E. Pace[2,3], J.A. Seman[2], G. Valtolina[2,4], M. Zaccanti[2], M. Inguscio[2], and G. Roati[2] — [1]ETH, Quantum Optics Group, Zurich, Switzerland — [2]INO-CNR and LENS, University of Florence, Sesto Fiorentino, Italy — [3]MIT-Harvard CUA, Massachusetts, USA — [4]SNS, Pisa, Italy

Ultra cold atoms are attracting a wide interest as a novel tool to address quantum many body physics in controlled environments. Laser light is used to tailor atomic potentials that recall condensed matter ones. This opens up a new way to study condensed matter physics. We describe here a new experimental apparatus which exploits quantum degeneracy of ^{6}Li. To produce larger atomic clouds, we developed for the first time on ^{6}Li, a sub doppler cooling scheme based on the D1 transition line [arXiv:1304.6971]. With all optical traps we are able to produce $2\times\ 10^5$ condensed molecules and a Fermi gas of $3\times\ 10^5$ atoms per spin state at 0.2 T/T_F. Our science chamber is endowed with many optical ports devoted to imaging from multiple directions and imprinting of tailored potentials. In the framework of quantum simulation we will study the properties of fermions superimposing an optical barrier of light to an atomic cloud, in this way producing double well potentials. The regime we are interested in is the thin barrier limit (currently 1.5 μm width), allowing the preparation of stable systems of two "adjacent" ($\sim k_F^{-1}$) oppositely polarised clouds. We aim at observing for the first time a clear evidence of the ferromagnetic ground state repulsion predicted for a fermionic mixture [arXiv:1308.1961v1].

Q 32.22 Wed 16:30 Spree-Palais

Experimental setup to probe a strongly interacting quasi two-dimensional Fermi gas — •Sebastian Pres[1], Martin Ries[1], Mathias Neidig[1], Andre Wenz[1], Puneet Murthy[1], Gerhard Zürn[1], Thomas Lompe[2], and Selim Jochim[1] — [1]Physikalisches Institut, Universität Heidelberg, INF 226, 69120 Heidelberg, Germany — [2]Department of Physics, Massachusetts Institute of Technology, Cambridge, MA, USA

We present our setup to probe a quasi two-dimensional gas of ultracold fermions in the strongly interacting regime.

We prepare a quantum degenerate quasi-2D sample of ^{6}Li atoms in the two lowest hyperfine states by performing evaporative cooling in an optical dipole trap and subsequently transferring the cloud into a standing wave optical dipole trap. The standing wave trap creates a stack of oblate potentials with a tight vertical confinement. Using radio-frequency tomography we can determine how many of the layers of the standing wave trap we populate and thus show that we can prepare a single realization of a quasi-2D Fermi gas by loading the sample into a single layer of the trap.

We use a matter wave focussing technique to directly access the initial in-situ radial momentum distribution of the sample in the trap. In the bosonic limit of deeply bound molecules, we observe a clear bimodal distribution which hints towards the formation of a quasi condensate. Evaluating this system as a function of interaction strength and temperature, we are able to investigate the 2D equivalent of the BEC-BCS crossover.

Q 32.23 Wed 16:30 Spree-Palais

Few-fermion systems in one dimension — •Gerhard Zürn[1], Andrea Bergschneider[1], Vincent Klinkhamer[1], Simon Murmann[1], Thomas Lompe[1,2,3], Andre N. Wenz[1], and Selim Jochim[1,3] — [1]Physikalisches Institut, Universität Heidelberg — [2]Department of Physics, Massachusetts Institute of Technology, Cambridge — [3]ExtreMe Matter Institute EMMI, GSI Darmstadt

Deterministically prepared samples of ultracold atoms are ideal benchmark systems to test theoretical models of few-fermion systems. We present experiments on ^{6}Li atoms in quasi one dimensional confining potentials with tunable interactions.

In one measurement, we perform radio frequency spectroscopy to measure the energy of a single impurity particle interacting repulsively with a defined number of identical majority particles of different spin. We study the crossover from single particles to the many-body limit by adding majority particles one by one. Within only four majority particles, we observe a fast convergence of the normalized interaction energy towards the analytic many-body prediction. Extending these measurements to higher dimensions would allow us to study polaronic physics. By adding impurity particles one by one into a large Fermi sea, we could study the emergence of polaron-polaron interactions.

Investigating attractively interacting systems, we observe that for increasing interaction strength the pair correlations in the system increase. These correlations lead to a strong odd-even effect of the separation energy of a single particle from the system, similar to the one observed for neutron separation experiments in nuclei.

Q 32.24 Wed 16:30 Spree-Palais

An ultracold mixture of metastable triplet He and Rb atoms — •Adonis S. Flores, Hari P. Mishra, Wim Vassen, and Steven Knoop — LaserLaB, VU University, Amsterdam, The Netherlands

We are working on an experiment to produce an ultracold atomic mixture of metastable He (^{3}He* or ^{4}He*) and ^{87}Rb. Our main goals are the observation of heteronuclear Efimov trimers and atom exchange reactions in collisions between atoms and Feshbach molecules. This requires the search for interspecies Feshbach resonances, needed to control the interaction between He* and Rb, and map out the near-threshold molecular He*Rb spectrum. Our strategy to obtain an ultracold He*+Rb mixture starts with a two-species MOT, loaded from a Zeeman slower (He*) and a 2D-MOT (Rb). Afterwards the mixture is loaded in a quadrupole magnetic trap (QMT) and a 1557-nm optical dipole trap for forced evaporative cooling. We have realized an ultracold mixture of ^{4}He* and ^{87}Rb in the QMT, for which Rb is prepared in the F=2, m$_F$=2 state, in order to suppress interspecies Penning ionization. Here we will discuss the status of the setup and the latest experimental data, in particular thermalization measurements from which the interspecies scattering length can be inferred.

Q 32.25 Wed 16:30 Spree-Palais

Non-equilibrium polaron physics of ultra cold bosonic lattice gases — •Fabian Grusdt[1,2], Aditya Shashi[2], Dmitry Abanin[2,3], and Eugene Demler[2] — [1]Department of physics, research center OPTIMAS and graduate school MAINZ, TU Kaiserslautern — [2]Physics Department, Harvard University — [3]Perimeter Institute, Waterloo, Canada

We discuss a single impurity in a one-dimensional optical lattice immersed in a homogeneous three dimensional superfluid Bose Einstein condensate. Interactions with the phonon modes of the latter lead to the formation of a stable quasi particle, the polaron. We investigate the static and dynamic properties of the polaron using a variational mean-field treatment. We consider the effect of an external driving force which drives subsonic Bloch oscillations of the polaron. In the weak coupling limit the polaron adiabatically follows its ground state and a detection of the polaron trajectory in real space can be used for a direct measurement of the renormalized polaron dispersion relation. We show that for stronger coupling the polaron trajectory is superimposed by a constant drift velocity, accompanied by polaron diffusion as well as phonon emission. We report on subtle deviations of the current- force relation from the standard Esaki-Tsu type expression and show that they can be explained by introducing an internal polaron structure.

Q 32.26 Wed 16:30 Spree-Palais

Imaging system for a two-species quantum degenerate gas — •Carmen Renner, Rico Pires, Juris Ulmanis, Stephan Häfner, Alda Arias, Marc Repp, Eva Kuhnle, and Matthias Weidemüller — Physikalisches Institut, Ruprecht-Karls-Universität Heidelberg, Germany

Taking absorption images of an atomic cloud is a standard method to study ultracold quantum gases. However, to extract accurate information about the cloud's properties by observing only a small number of atoms, it requires spatial resolution, minimized optical aberrations and appropriate magnification while using a camera with high sensitivity. In our experiment, imaging is even more complicated since we prepare a mixture of ultracold ^{6}Li and ^{133}Cs gases, so that resolved imaging for these species requires two different imaging wavelengths, 671 nm and 852 nm respectively, for which the imaging system has to be optimized. This poses the challenge of chromatic aberrations. Initial estimations of those errors were considered with ray tracing. In this poster we will present the setup of our dual-wavelength imaging system that is designed to study collisional properties and dynamics of a quantum degenerate mixture of ^{133}Cs and ^{6}Li.

Q 32.27 Wed 16:30 Spree-Palais

Towards light induced spin-orbit coupling for ultra-cold neutral atoms — •Sebastian Bode, Felix Kösel, Holger Ahlers, Katerine Posso Trujillo, Naceur Gaaloul, and Ernst Rasel — IQ Universität Hannover

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).

Q 32.28 Wed 16:30 Spree-Palais

BEC dynamics in the presence of a synthetic magnetic field — •Andrey R. Kolovsky[1], Fabian Grusdt[2], and Michael Fleischhauer[2] — [1]Siberian Federal University, 660049 Krasnoyarsk, Russia — [2]TU Kaiserslautern, 67663 Kaiserslautern, Germany

We study dynamics of BEC of non-interacting atoms in a 2D parabolic lattice (i.e., the lattice plus harmonic confinement) in the presence of a synthetic magnetic field. The analysis is preceded by thorough consideration of the single-particle spectrum of the system. We show that generally this spectrum consists of two, regular and chaotic components. The relative fraction of chaotic eigenstates depends on the mean energy of an atom and changes from zero to one when the energy is increased. This property of the system is reflected in BEC dynamics which we assume to be induced by a sudden shift of the harmonic trap origin or by a time-dependent flux (a circular electric field).

Q 32.29 Wed 16:30 Spree-Palais

Cavity QED in the Recoil Resolved Regime — •Hans Kessler, Jens Klinder, Matthias Wolke, and Andreas Hemmerich — Institut für Laserphysik, Universität Hamburg

We are experimentally exploring the light matter interaction of a Bose-Einstein condensate (BEC) with the light mode of an ultrahigh finesse optical cavity ($F \approx 340\,000$). The key feature of our cavity is the small intracavity field decay rate ($\kappa/2\pi \approx 4.5\,\text{kHz}$), which is half the spectral width of the transmission resonances. Most importantly, this decay rate is smaller than twice the recoil frequency ($\omega_{\text{rec}}/2\pi \approx 3.55\,\text{kHz}$) or rather the spectral linewidth is smaller than the frequency change of a photon in a single backscattering event. Together with a Purcell factor of $\eta \approx 40 \gg 1$, this leads to a unique situation where each atom can backscatter only a single photon, because the kinetic energy transfer required for further backscattering is not resonantly supported by the cavity. With our setup we were able to demonstrate targeted heating and cooling of atoms on a sub-recoil energy scale at densities on the order of $10^{14}\,\text{cm}^{-3}$ incompatible with conventional laser cooling which relies on the scattering of near resonant photons [1].

Furthermore, the inaccessibility of higher momentum states leaves us with a true two level system interacting with our narrowband cavity. This model system gives us the opportunity to investigate novel aspects of light matter interaction like exotic quantum phase transitions or attractors in cavity optomechanics.

[1] M. Wolke, J. Klinner, H. Keßler, and A. Hemmerich, Science 337, 75 (2012)

Q 32.30 Wed 16:30 Spree-Palais

Orbital Physics with Ultracold Fermions in Higher Bands of an Optical Lattice — •Arne Ewerbeck, Robert Büchner, Thorge Kock, Matthias Ölschläger, and Andreas Hemmerich — Institut für Laser-Physik, Universität Hamburg, Luruper Chaussee 149, 22761 Hamburg

We report on the progress of setting up a new bose-fermi mixture experiment to investigate atoms in higher bands of an optical lattice. A current status of the experimental setup and details on the planned optical lattice are given. We plan to synthesise optical lattice models, much closer to relevant, yet marginally understood condensed matter systems (e.g., high Tc-superconductors) than presently available.

Q 32.31 Wed 16:30 Spree-Palais

Ultracold bosons in optical lattices subjected to a periodic perturbation — •Karla Loida and Corinna Kollath — HISKP, University of Bonn, Nussallee 14-16, D-53115 Bonn, Germany

In recent years ultracold atomic gases in optical lattices have developed into a powerful tool to mimick condensed matter phenomena. The unique control of parameters has enabled the engineering of sophisticated quantum systems. In particular with the experimental realization of effectively strong and tunable atomic interactions the area of strongly correlated systems has entered the focus of interest. In such systems, the emergent phenomena are governed by the interplay of a macroscopic number of atoms. Theoretically, atomic gases in optical lattices are described by various kinds of Hubbard models which may be cleanly realized in cold atom experiments. Even more exciting are these systems as one finally gains access to the dynamics of many-body theory which are of fundamental interest but so far little understood. One example is the time evolution of the propagation of correlation.

We study non-equilibrium situations in the one dimensional Bose-Hubbard model which are governed by the interplay of local interaction and kinetic processes. The Bose-Hubbard model exhibits a phase transition between a Mott insulating and a superfluid phase. We probe the Mott insulating phase by applying a periodic perturbation. This periodic driving can experimentally easily be implemented by adding an additional laser wave incommensurate with the underlying optical lattice. We study how the system responds using an approximative approach based on fermionic quasiparticles.

Q 32.32 Wed 16:30 Spree-Palais

High-Order Strong-Coupling Expansion for Bose-Hubbard Model — Tao Wang[1,2], Xue-Feng Zhang[1], Sebastian Eggert[1], and •Axel Pelster[1] — [1]Physics Department and Research Center OPTIMAS, Technische Universität Kaiserslautern, Germany — [2]Department of Physics, Harbin Institute of Technology, China

We apply the process-chain method [1,2] in order to calculate the quantum phase boundary between the Mott insulator and the superfluid phase for bosons in a hypercubic optical lattice within the strong-coupling method [3]. The respective results in 1d, 2d, and 3d, which are obtained up to 12th order and then extrapolated to infinite order, turn out to coincide almost with high-precision Quantum-Monte Carlo results. Finally, we show that these high-order strong-coupling results also follow from a high-order effective potential calculation [2,4,5].

[1] A. Eckardt, Phys. Rev. B **79**, 195131 (2009)
[2] N. Teichmann, D. Hinrichs, M. Holthaus, and A. Eckardt, Phys. Rev. B **79**, 224515 (2009)
[3] J. K. Freericks and H. Monien, Phys. Rev. B **53**, 2691 (1996)
[4] F. E. A. dos Santos and A. Pelster, Phys. Rev. A **79**, 013614 (2009)
[5] D. Hinrichs, A. Pelster, and M. Holthaus, Appl. Phys. B **113**, 57 (2013)

Q 32.33 Wed 16:30 Spree-Palais

Hamiltonian quantum rocking ratchets with ultracold rubidium atoms in an 1D optical lattice — •Christopher Grossert[1], Martin Leder[1], Martin Weitz[1], Sergey Denisov[2], and Peter Hänggi[2] — [1]Institute of Applied Physics, University of Bonn, Germany — [2]Physics Institute, University of Augsburg, Germany

In periodically driven systems a breaking of spatiotemporal symmetry can lead to directed motion in the absence any gradients or net forces. A biharmonic driving is sufficient to break the relevant symmetries in the classical case [1] as well as in the quantum case [2]. For a dissipative system, this so called rocking ratchet system has been studied in previous work [3]. We here report on the experimental realization of a Hamiltonian quantum rocking ratchet with ultracold ^{87}Rb atoms in a 1D optical lattice with biharmonic frequency driving. Other than in previous work of our group [4], the Hamiltonian rocking ratchet transport operates with sinusoidally shaped standing wave optical lattices. In the rocking ratchet system, we observe unique features of a quantum ratchet resonance in control parameter space and bifurcation of quantum resonances as well as a dependence of the atom transport on the initial time of the modulation.

[1] S. Flach et al., Phys. Rev. Lett. **84**, 2358 (2000)
[2] Denisov et al., Phys. Rev. A **75**, 063424 (2007)
[3] Schiavoni et al., Phys. Rev. Lett. **90**, 094101 (2003)
[4] Salger et al., Science **326**, 1241 (2009)

Q 32.34 Wed 16:30 Spree-Palais

Mott insulator to superfluid transition of ultracold bosons in an optical lattice by periodic driving — •Christoph Sträter and André Eckardt — Max-Planck-Institut für Physik komplexer Systeme, Dresden

We study the hybridization of Bloch bands of ultracold quantum gases in optical lattice potentials. To overcome the band gap between the lowest Bloch band and higher excited bands, we consider a scheme where the lattice is driven by an external time-periodic force. By the resulting AC-force on the particles, the bands are coupled coherently and thus hybridize. With the help of Floquet theory we derive effective time-independent Hubbard models describing the band-coupled system. Within this framework we study the melting of a bosonic Mott-insulator as a result of the coherent band coupling. We analyze the respective phase diagram of the bosonic ground state and in addition simulate an experimental protocol, in which the phase transition is achieved by an adiabatic tuning of the driving frequency.

Q 32.35 Wed 16:30 Spree-Palais

Quantum dynamics of spin waves in ultracold bosonic systems — •Frauke Seesselberg[1], Sebastian Hild[1], Takeshi Fukuhara[1], Peter Schauss[1], Johannes Zeiher[1], Immanuel Bloch[1,2], and Christian Gross[1] — [1]Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Straße 1, 85748 Garching, Germany — [2]Fakultät für Physik, Ludwig-Maximilians-Universität München, Schellingstraße 4, 80799 München, Germany

Ultracold quantum gases in optical lattices are promising candidates to simulate spin Hamiltonians, which describe a variety of different phenomena. Single-site resolved imaging of a single spin species allows for the spatially resolved measurement of spin-spin correlations. The atomic Mott insulator corresponds to a spin polarized state with very low entropy. Together with precise local or global spin manipulation, this allows for the study of the dynamics of precisely defined initial spin states.

We report on experiments studying the dynamics of bound and free magnons following local spin flips as well as globally imprinted spin spirals, which are highly excited states of the system. The ability to control the tunneling rate in the ultracold atomic gas allows us to study the scaling behavior of the spin spiral lifetime in one and two dimensions. The data is compared with theoretical predictions based on direct diagonalization.

Q 32.36 Wed 16:30 Spree-Palais

Towards ultracold fermions in a 2D honeycomb lattice — •Thomas Paintner, Daniel Hoffmann, Michael Griener, Jochen Gleiter, Wladimir Schoch, Wolfgang Limmer, Benjamin Deissler, and Johannes Hecker Denschlag — Institut für Quantenmaterie, Universität Ulm, Deutschland

We are setting up a new experiment with ultracold fermionic atoms in a two-dimensional honeycomb lattice to investigate intriguing phenomena which are either related to relativistic quantum physics (e.g. Zitterbewegung, Klein tunnelling) or to condensed matter physics (quantum phases, quantum criticality). This system has the underlying geometry of graphene, but can be tuned and controlled in a much greater range. Fermionic 6Li atoms are captured in a magneto-optical trap and loaded into a strong optical dipole trap. In the next steps, the atoms will be transferred optically into a glass cell and loaded into a 2D optical trap created by blue-detuned laser beam with a TEM01 mode. We will present the experimental progress towards a two-dimensional degenerate Fermi gas, as well as results on the projection of a honeycomb potential created with a holographic phase plate.

Q 32.37 Wed 16:30 Spree-Palais

Dissipation through localised loss in bosonic systems with long-range interactions — •Ivana Vidanovic, Daniel Cocks, and Walter Hofstetter — Institut für Theoretische Physik, Johann Wolfgang Goethe-Universität, Frankfurt am Main Germany

In the recent years, controlled dissipation has proven to be a useful tool for probing of a quantum system in the ultracold setup. In this paper we consider dynamics of bosons induced by a dissipative local defect. We address superfluid and supersolid phases that are ground states of an extended Bose-Hubbard Hamiltonian. To this end, we solve the master equation using the Gutzwiller approximation and find that in the usual homogeneous superfluid phase repulsive interactions lead to enhanced dissipation process. On the other hand, our mean-field approach indicates that the effective loss rates are significantly suppressed deep in the supersolid phase where repulsive nearest neighbour interactions play a dominant role. Our numerical results are explained by an analytical insight and in particular, in the limit of strong dissipation we recover the quantum Zeno effect.

Q 32.38 Wed 16:30 Spree-Palais

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

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

Q 32.39 Wed 16:30 Spree-Palais

Spectroscopy of ultracold Fermions in Triangular Optical Lattices using ultranarrow Opical Transitions — Alexander Thobe, •Bastian Hundt, André Kochanke, Thomas Ponath, Niels Petersen, Christoph Becker, and Klaus Sengstock — Zentrum für Optische Quantentechnologien, Universität Hamburg, Luruper Chaussee 149, 22761 Hamburg, Germany

Quantum gases of two-electron atoms in optical lattices offer exciting new possibilities within the field of ultracold atoms. Especially the spin-independent ground state interaction, as well as the long lived metastable ${}^3P_{0,2}$ states allow the realization of novel many-body Hamiltonians.

Here, we report on our recent experiments with ultracold Ytterbium quantum gases in a triangular optical lattice. In our 2D-/3D-MOT setup, we prepare quantum degenerate gases of fermionic ^{173}Yb with 1 to 6 spin components. In order to investigate the interaction properties of the metastable ${}^3P_0$-state, we perform spectroscopy on the narrow ${}^1S_0 - {}^3P_0$ clock transition of the ultracold atomic sample. To this end, we load the atoms into a triangular optical lattice at the magic wavelength, where the transition is probed with a stable laser system exhibiting a linewidth of a few Hz.

This work is supported by the DFG within the SFB 925 and GRK 1355, the EU FET-Open Scheme (iSense), and the Marie-Curie ITN on Quantum Sensor Technologies and Applications.

Q 32.40 Wed 16:30 Spree-Palais

Dynamics of Quantum-Systems with Localized Dissipation — •Ralf Labouvie, Andreas Vogler, Simon Heun, Bodhaditya Santra, and Herwig Ott — Fachbereich Physik and Research Center OPTIMAS, Technische Universität Kaiserslautern, 67663 Kaiserslautern, Germany

In our experiment, we are employing a tightly focussed scanning electron-beam on ultra-cold atoms to locally remove particles. This allows us to probe atomic density distributions with high temporal and spatial resolution. Furthermore, the electron-beam is a versatile tool to manipulate the atomic ensemble e.g. it yields the possibility for localized dissipative defects and therefore to create open quantum-systems. The obtained signal shows the system's reaction on the defect and allows to measure pair-correlations and Zeno-like behaviour. This method can also be used to engineer non-equilibrium states and investigate their time evolution e.g. tunnel dynamics in an one-dimensional optical lattice. In addition, subsequently obtained density-profiles allow for an in-vivo investigation of all the samples.

Q 32.41 Wed 16:30 Spree-Palais

Realization of a finite-size optical lattice for cold fermionic atoms — •Simon Murmann[1], Andrea Bergschneider[1], Vincent Klinkhamer[1], Gerhard Zürn[1], Thomas Lompe[1,2], and Selim Jochim[1] — [1]Physikalisches Institut der Universität Heidelberg, INF 226, 69120 Heidelberg, Germany — [2]Department of Physics, Massachusetts Institute of Technology, Cambridge, MA, USA

We report on the realization of an experimental setup for the deterministic preparation of cold fermionic atoms in multiple-well potentials. Starting with a setup for the preparation of few-atom samples in the vibrational ground state of one tightly focused dipole trap, we expanded our experiment using an acousto-optic deflector (AOD) to split the trapping light into multiple orders forming one potential well each. Both depth and position of the individual wells can be changed independently, allowing the creation of a tunable finite-size optical lattice.

For two atoms in a double-well potential we report on the full control over the quantum state. Preparing the atoms in the ground state of the double-well potential, a finite interparticle interaction leads to a change in particle statistics. For strong repulsive (attractive) interactions we measure a strong enhancement (suppression) of singly occupied sites. In terms of a finite Fermi-Hubbard model this can be understood as a two-particle analogy to a Mott-insulator (charge-density wave). Adding more wells to the systems we aim for a bottom-up approach to Fermi-Hubbard physics. Further, prospects for experiments in dynamically changing potentials are presented.

Q 32.42 Wed 16:30 Spree-Palais

A K-Rb setup for the creation of topological states in a honeycomb lattice — •Tracy Li[1,2], Lucia Duca[1,2], Martin Reitter[1,2], Monika Schleier-Smith[1,2], Josselin Bernadoff[1,2], Henrik Lüschen[1,2], Immanuel Bloch[1,2], and Ulrich Schneider[1,2] — [1]Ludwig-Maximilians-Universität-München, München, Germany — [2]Max-Planck-Institut für Quantenoptik, Garching, Germany

We present an apparatus for studying topological states of a two-dimensional degenerate Fermi gas in a honeycomb lattice. In this double species experiment, fermonic ^{40}K atoms are sympathetically cooled to quantum degeneracy in a bath of ^{87}Rb atoms. The fermions are then adiabatically compressed into a single layer of a vertical 1D lattice.

The honeycomb lattice contains the well-known graphene band structure with two Dirac points in the lowest band. A variety of methods can be used to create a band gap at the Dirac points, changing the topology of the band structure. We plan to investigate both periodic modulations of the hopping amplitudes by modulating the lattice beam amplitudes and the creation of an optical flux lattice. In the former method, depending on the strength of the modulation, the system exhibits different topological phases with nonzero Chern number or nonzero winding number. In the latter method, a spatially varying Raman coupling is combined with a spin-dependent potential, creating a high magnetic flux system that is a good candidate for accessing the quantum Hall regime.

We present our plans for implementing this setup and characterizing its topological character and the current status of our experiment.

Q 32.43 Wed 16:30 Spree-Palais

Out-of-equilibrium dynamics of bosons in optical lattices — •Henrik Lüschen[1,2], Simon Braun[1,2], Michael Schreiber[1,2], Pranjal Bordia[1,2], Frederik Görg[1,2], Pau Gomez[1,2], Sean Hodgman[1,2], Immanuel Bloch[1,2], and Ulrich Schneider[1,2] — [1]Max-Planck-Institut für Quantenoptik, Garching — [2]Ludwig-Maximilians-Universität, München

Out-of-equilibrium dynamics of many-body systems, such as transport phenomena and thermalization, represent an active and challenging research field in strongly interacting systems. We use an ultracold bosonic gas in an optical lattice to study the out-of-equilibrium dynamics in the Bose-Hubbard model.

Specifically, we investigate the emergence of coherence when crossing the phase transition from the Mott insulating to the superfluid regime by studying the coherence length of the final state in 1D, 2D and 3D. We find a power-law increase with quench time and exponents that depend on the final interaction strength. These exponents differ significantly from the Kibble-Zurek prediction but are in good agreement with exact diagonalization calculations. We observe a strong symmetry in the emergence of coherence between positive and negative temperatures.

Additionally, we study the expansion dynamics of interacting bosons released into a homogeneous lattice. While the real space dynamics highlight the difference between ballistic and diffusive transport, the momentum space analysis reveals evidence of quasi-condensation of expanding hard-core bosons in 1D.

Q 32.44 Wed 16:30 Spree-Palais

Realization of the Hofstadter Hamiltonian with ultracold atoms in optical lattices — •Michael Lohse[1,2], Monika Aidelsburger[1,2], Marcos Atala[1,2], Julio Barreiro[1,2], Belén Paredes[3], and Immanuel Bloch[1,2] — [1]Fakultät für Physik, Ludwig-Maximilians-Universität, Schellingstrasse 4, 80799 München, Germany — [2]Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Strasse 1, 85748 Garching, Germany — [3]Instituto de Física Teórica CSIC/UAM C /Nicolás Cabrera, 13-15 Cantoblanco, 28049 Madrid, Spain

We developed a new experimental technique to simulate strong uniform artificial magnetic fields on the order of one flux quantum per plaquette with ultracold atoms in optical lattices. Using laser-assisted tunneling in a tilted optical lattice we engineer complex tunneling amplitudes - so called Peierls phases - whose value depends on the position in the lattice. Thereby, atoms hopping in the lattice accumulate a phase shift equivalent to the Aharonov-Bohm phase of charged particles in a magnetic field. We determine the local distribution of fluxes through the observation of cyclotron orbits of the atoms on isolated four-site square plaquettes. Furthermore, we show that for two atomic spin states with opposite magnetic moments, our system naturally realizes the time-reversal-symmetric Hamiltonian underlying the quantum spin Hall effect; i.e., two different spin components experience opposite directions of the magnetic field.

Q 32.45 Wed 16:30 Spree-Palais

Observation of the Meissner effect in bosonic ladders — •Marcos Atala[1,2], Monika Aidelsburger[1,2], Michael Lohse[1,2], Julio Barreiro[1,2], Belén Paredes[3], and Immanuel Bloch[1,2] — [1]Fakultät für Physik, Ludwig-Maximilians-Universität, Schellingstrasse 4, 80799 München, Germany — [2]Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Strasse 1, 85748 Garching, Germany — [3]Instituto de Física Teórica CSIC/UAM C /Nicolás Cabrera, 13-15 Cantoblanco, 28049 Madrid, Spain

We implemented a large uniform effective magnetic field with ultracold atoms using laser-assisted tunneling in a ladder created with an optical lattice. Depending on the ratio between the coupling along the rungs of the ladder and the one along the legs of the ladder, the system presents two different phases: the vortex phase, where the probability currents along the bonds have a vortex structure, and the Meissner phase where the currents form a single vortex of infinite length. In order to detect the probability currents associated to the different phases we populated the ground state of the flux ladder and subsequently projected the state into isolated double well potentials that allowed us to measure the average current direction and strength. We observed the different behavior of the current in both regimes. Furthermore, we also measured the time-of-flight momentum distribution of the ground state for different lattice parameters.

Q 32.46 Wed 16:30 Spree-Palais

Engineering band structures for fermions in a triangular optical lattice — Nick Fläschner, •Dominik Vogel, Frieder Fröbel, Jasper Simon Krauser, Jannes Heinze, Christof Weitenberg, Klaus Sengstock, and Christoph Becker — Universität Hamburg, Institut für Laserphysik, Germany

Quantum gases in optical lattices offer a wide range of applications for quantum simulation due to widely tunable lattice and atomic interaction parameters. In this poster, we discuss experimental aspects and recent results of our setup for fermionic 40K in a far detuned triangular lattice. In particular, we report on high resolution spectroscopy with full momentum resolution, conducted via modulating the lattice depth. This method permits us to accurately extract the full two dimensional band structure. We present further how the band structure can be modified over a wide range of parameters by modulating the phases of the lattice beams. These parameters include the signs and the complex phases of the tunneling matrix elements, as well as controlling different bonds individually. In combination, these techniques form a versatile toolkit for precisely engineering band structures, creating artificial gauge fields and enabling future studies of interacting fermionic mixtures in non-cubic optical lattices.

Q 32.47 Wed 16:30 Spree-Palais

Beyond Artificial Graphene with Ultracold Fermions in a Tunable-Geometry Optical Lattice — •Gregor Jotzu, Thomas Uehlinger, Michael Messer, Daniel Greif, and Tilman Esslinger — Institute for Quantum Electronics, ETH Zurich, 8093 Zurich, Switzerland

Ultracold fermions in optical lattices offer the possibility to simulate the behaviour of solids and explore regimes which are not accessible in current materials. We have created an articificial Graphene-like system and study how it can be driven from the usual Dirac-metal state to various insulating states (including the first implementation of a 2D Mott-insulator of fermions) by changing interactions, on-site energies or the tunneling structure. We present recent results on the behaviour of static and dynamic observables in insulating regimes.

Q 32.48 Wed 16:30 Spree-Palais

Dynamical synthetic gauge fields, string order and correlated phases with periodically modulated interactions — •Sebastian Greschner[1], Gaoyong Sun[1], Dario Poletti[2], and Luis Santos[1] — [1]Institut für Theoretische Physik, Leibniz Universität Hannover, Appelstr. 2, DE-30167 Hannover, Germany — [2]Engineering Product Development, Singapore University of Technology and Design, 20 Dover Drive, 138682 Singapore

A periodic modulation of the magnetic field in the vicinity of a Feshbach resonance induces periodically modulated interactions, which result in a non-linear hopping rate depending on the occupation differences at neighboring sites. We show different scenarios in which dynamical synthetic gauge fields may be engineered using periodically modulated interactions. We analyse in detail the experimental signatures of the created fields and their detection and present simulations of the dynamical preparation of the effective model groundstates. We further discuss how the combined periodic modulation of optical lattices and interactions may be used to realize a very broad class of correlated hopping Hubbard models and study the rich physics of this scenario, including pair-superfluidity, dimerized phases as well as exotic Mott-insulator states with a non-vanishing string-order.

Q 32.49 Wed 16:30 Spree-Palais

Ultracold Fermions in Optical Superlattices — •Pranjal Bordia[1,2], Michael Schreiber[1,2], Frederik Goerg[1,2], Henrik Lueschen[1,2], Sean Hodgman[1,2], Pau Gomez[1,2], Simon Braun[1,2], Immanuel Bloch[1,2], and Ulrich Schneider[1,2] — [1]Ludwig-Maximilians-Universitaet, Muenchen — [2]Max-Planck-Institut fuer Quantenoptik, Garching

Quantum simulations using ultracold fermions in optical lattices present many possibilities to study the fermionic Hubbard model in a clean and highly tunable system. In recent years, these systems have been used to study e.g. the fermionic Mott insulator and the various charge dynamics.

We have implemented an optical superlattice along one direction in order to explore different staggered orders. Within individual double wells, it facilitates the observation of singlet-triplet oscillations, and super-exchange interactions for fermionic atoms. Furthermore, this enables us to explore the equilibrium physics as well as the out-of-equilibrium dynamics of e.g. charge-density waves and magnetically ordered states. We report our recent results and future goals.

Q 32.50 Wed 16:30 Spree-Palais

Non-equilibrium dynamics in ion Coulomb crystals — •Ramil Nigmatullin[1] and Martin Plenio[2] — [1]Institute of Quantum Physics, University of Ulm, Ulm, Germany — [2]Institute of Theoretical Physics, University of Ulm, Ulm, Germany

Recent experiments [1-3] studied the process of formation of topological defects in ion Coulomb crystals following non-equilibrium symmetry breaking phase transitions. In these experiments topological defects (kinks) were created by rapidly transforming a linear chain into a zigzag configuration. The measured scaling of the average number of defects as a function of quench rate is the first accurate measurement of the universal Kibble-Zurek scaling law in the inhomogeneous system.

Structural defects in ion Coulomb crystals are examples of discrete solitons. Discrete solitons are non-linear structures with rich complex dynamics. Ion Coulomb crystals provide an excellent platform for exploring both classical and quantum dynamics of discrete solitons. A number of recent experimental and theoretical works [4] examine the dynamics of discrete solitons in ion traps, in particular focusing on the phonon spectra, Peierls-Nabarro potential, effect of molecular ions and kink-kink interactions.

[1] - K. Pyka et al, Nature Comm. 4, 2291 (2013).
[2] - S. Ulm et al, Nature Comm. 4, 2290 (2013).
[3] - S. Ejtemaee and P. C. Haljan, Phys. Rev. A 87, 051401 (2013).
[4] - H. L. Partner et al, New J. Phys., 15 103013 (2013)

Q 32.51 Wed 16:30 Spree-Palais

Basic properties of a dipolar Bose-Einstein condensate with dysprosium — •Damir Zajec and Günter Wunner — 1. Institut für theoretische Physik, Universität Stuttgart

Dipolar Bose-Einstein condensates open the field of research of effects which are generated by the dipole-dipole interaction such as self-organization and pattern formation. One promising candidate for realizing a dipolar BEC is dysprosium, which has a dipolar moment of 10 Bohr magnetons. We perform grid calculations to determine the ground states of a dipolar BEC with dysprosium by means of the Gross-Pitaevskii equation. The split-operator method is used to apply a general time evolution operator to an initial state, where time evolution is mainly described by a series of Fourier transforms. Since this numerical scheme is computationally very demanding, the parallel computing architecture CUDA was used to implement the code. We present calculations of the dynamic expansion of the BEC and a stability diagram with respect to the orientation of the dipoles and the aspect ratio of the external confinement.

Q 32.52 Wed 16:30 Spree-Palais

Collisional frequency shifts and spin-squeezing for a trapped-atom clock — •Konstantin Ott[1,2], Ramon Szmuk[1], Vera Guarrera[1], Wilfried Maineult[2], Jakob Reichel[2], and Peter Rosenbusch[1] — [1]LNE-SYRTE, Observatoire de Paris, France — [2]LKB, Ecole Normale Supérieure, Paris, France

Atomic clocks are probably the most accurate and stable instruments and lead to many scientific and technological applications. As an innovative approach we operate a trapped atom clock on a chip (TACC) using magnetically trapped ^{87}Rb atoms.

Contrary to standard atomic clocks, where the atoms are in free flight, the trap allows reaching ultra-low temperatures and BEC, long observation times (only vacuum limited) and micro-scale positioning. It increases the density $10^4\times$ and hence the effects of interactions. Under these ideal conditions, we have observed the opening of an energy gap between the symmetric and anti-symmetric two-body-wavefunction describing colliding atoms. The energy gap inhibits dephasing such that extraordinarily long coherence times (58 s) can be reached [PRL 105, 020401 (2010), PRL 109, 020407 (2012)].

Here we present plans for a second generation set-up, now also including a microscopic optical fiber cavity [NJP 12, 065038 (2010)]. The cavity will be used for quantum non-demolition detection [PRL 104, 073604 (2010), PRL 106, 133601 (2011)] and the creation of spin-squeezing [PRL 104, 073602 (2010)]. We expect to reach clock stabilities below 10^{-13} at 1s, better than existing compact clocks.

Q 32.53 Wed 16:30 Spree-Palais

Perturbative Hydrodynamics of 1d Bose-Einstein Condensate with Ring Geometry in Weak Disorder Potential — Davron Abdullaev[1], Bakhodir Abdullaev[1], •Branko Nikolić[2], and Axel Pelster[3] — [1]Institute of Applied Physics, National University of Uzbekistan, Tashkent, Uzbekistan — [2]Department of Physics, Freie Universität Berlin, Germany — [3]Fachbereich Physik und Forschungszentrum OPTIMAS, Technische Universität Kaiserslautern, Germany

The hydrodynamic properties of a dilute stationary Bose-Einstein condensate are determined from solving the coupled continuity and Euler equations. Here we develop a perturbative solution approach by assuming that the disorder potential is weak. In this way we find explicit expressions for the ensemble averages of both the condensate and the superfluid density as well as of the superfluid velocity for a Lorentzian correlated disorder. In the special case of a delta correlated disorder in 3d the results reduce to the ones derived originally by Huang and Meng [1-4]. Furthermore, we specialize our results to Bose-Einstein condensates with a quasi 1d ring geometry which have been experimentally realized in different laboratories worldwide. In particular, we discuss how the ring length affects the respective hydrodynamic properties.

[1] K. Huang, H.-F. Meng, Phys. Rev. Lett. **69**, 644 (1992)
[2] C. Krumnow and A. Pelster, Phys. Rev. A **84**, 021608(R) (2011)
[3] B. Abdullaev and A. Pelster, Europ. Phys. J. D **66**, 314 (2012)
[4] B. Nikolic, A. Balaz, and A. Pelster, Phys. Rev. A **88**, 013624 (2013)

Q 32.54 Wed 16:30 Spree-Palais

Bose-Einstein Condensates with Strong Disorder – Gaussian Approximation for Correlation Functions — •Branko Nikolić[1], Antun Balaž[2], and Axel Pelster[3] — [1]Department of Physics, Freie Universität Berlin, Germany — [2]Scientific Computing Laboratory, Institute of Physics Belgrade, University of Belgrade, Serbia — [3]Fachbereich Physik und Forschungszentrum OPTIMAS, Technische Universität Kaiserslautern, Germany

Ultracold bosonic atoms in potentials with quenched disorder represent a notoriously difficult problem due to the competition of localization and superfluidity. Whereas some initial promising results are known for weak disorder within a Bogoliubov theory of dirty bosons [1], the case of strong disorder is still quite elusive [2]. Here we work out a non-perturbative approach towards the dirty boson problem at zero temperature which is based on a Gaussian approximation for correlation functions of the disorder potential and the condensate wave function solving the Gross-Pitaevskii equation. For contact interaction we find that the case of delta-correlated disorder can be treated analytically, whereas the case of a Lorentzian disorder correlation necessitates a numerical solution of a set of self-consistency equations. For weak disorder we reproduce the condensate depletion of Huang and Meng and for strong disorder we yield a quantum phase transition to a Bose-glass phase.

[1] K. Huang, H.-F. Meng, Phys. Rev. Lett. **69**, 644 (1992)

[2] P. Navez, A. Pelster, and R. Graham, Appl. Phys. B **86**, 395 (2007)

Q 32.55 Wed 16:30 Spree-Palais

Bose-Einstein Condensation with Strong Disorder – Replica Method — •Tama Khellil[1], Antun Balaž[2], and Axel Pelster[3] — [1]Department of Physics, Freie Universität Berlin, Germany — [2]Scientific Computing Laboratory, Institute of Physics Belgrade, University of Belgrade, Serbia — [3]Fachbereich Physik und Forschungszentrum OPTIMAS, Technische Universität Kaiserslautern, Germany

A recent non-perturbative approach towards the dirty boson problem relies on applying the replica method [1]. Here we extend this Hartree-Fock theory for a weakly interacting Bose-gas in a quenched delta-correlated disorder potential from the homogeneous case to a harmonic confinement within the Thomas-Fermi approximation. In this way we obtain and solve coupled self-consistency equations which involve the particle and the condensate density as well as the density of fragmented local Bose-Einstein condensates, which emerge in the respective minima of the random potential landscape. Whereas for weak disorder the results of Huang and Meng from a Bogoliubov theory [2,3] are reproduced only qualitatively, we yield for strong disorder a quantum phase transition to a Bose-glass phase.

[1] R. Graham and A. Pelster, I. J. Bif. Chaos **19**, 2745 (2009)

[2] K. Huang, H.-F. Meng, Phys. Rev. Lett. **69**, 644 (1992)

[3] G.M. Falco, A. Pelster, and R. Graham, Phys. Rev. A **75**, 063619 (2007)

Q 32.56 Wed 16:30 Spree-Palais

Absorption and transport properties of quantum aggregates with heavy-tailed disorder — •Sebastian Möbius[1], Sebastiaan M. Vlaming[1], Victor A. Malyshev[2], Jasper Knoester[2], and Alexander Eisfeld[1] — [1]Max Planck Intitute for physics of complex systems, Dresden, Germany — [2]Centre for Theoretical Physics and Zernike Institute for Advanced Materials, University of Groningen, Netherlands

Molecular aggregates exhibit extraordinary absorption properties, depending on their geometrical conformation and inter-monomeric coupling. The narrowing of the absorption band for J-aggregates can be well described by diagonal Gaussian static disorder for individual site energies. Aggregates consisting of large molecules are usually embedded in complex environments, making it impossible to separate individual contribution to the energy fluctuations.

Recent developments in generating and trapping highly excited Rydberg atoms, allow for quantum simulations of molecular aggregates. We show that by controlling the environment, e.g. a polar background gas, non-Gaussian static disorder can be studied. We analyze how the environment generates disorder distributions with heavy tails, so called Lévy-stable distributions, and discuss novel effects in Levy disordered systems such as broadening of the absorption bandwidth [1] as well as a subdiffusive exciton transfer.[2]

[1] A. Eisfeld, S.M. Vlaming, V.A. Malyshev, J. Knoester, PRL 105, 137402 (2010) [2] S.M. Vlaming, V.A. Malyshev, A. Eisfeld, J. Knoester, JCP 138, 214316 (2013)

Q 32.57 Wed 16:30 Spree-Palais

Phase-coherent quantum propagation in disordered media — •Valentin V. Volchkov[1], Fred Jendrzejewski[1,3], Kilian Müller[1], Jeremie Richard[1], Philippe Bouyer[2], Alain Aspect[1], and Vincent Josse[1] — [1]Laboratoire Charles Fabry, Palaiseau, France — [2]LP2N, Talence, France — [3]Joint Quantum Institute, Gaithersburg, USA

Quantum interference effects play a fundamental role in our understanding of quantum propagation through disordered media, as it can lead to the suppression of transport, i.e. Anderson Localization. Recently it became possible to directly observe Anderson Localization with ultracold atoms[1]. For weak disorder, a first order manifestation of coherence is the phenomenon of coherent backscattering (CBS), i.e. the enhancement of the scattering probability in the backward direction, due to a quantum interference of amplitudes associated with two counter propagating multiple scattering paths.

Such a CBS peak can be directly observed by launching atoms with a well-defined momentum into a laser speckle disordered potential[2]. We study the dynamics of the CBS peak during the diffusion as a function of disorder strength.

Q 32.58 Wed 16:30 Spree-Palais

Cavity cooling of an atomic array in the presence of the spontaneous emission — •Oxana Mishina and Giovanna Morigi — Saarland University, Saarbruecken 66123, Germany

We present the theoretical investigations of the cavity cooling scheme in application to an atomic array. Following the experimental demonstration of a collective cooling of the array [1] we propose the scheme to cool not only one collective mode of atomic motion but all the atoms to the ground stated of the individual traps. Taking in to account the limitations due to the scattering in to the outer cavity modes we find the conditions when the cooling of tens of atoms is experimentally feasible within a 10 ms time. Additionally we show that the collective effects slow down the cooling in comparison with the single atom cooling case and they also cause a stronger requirement for overcoming the limitations imposed by the spontaneous emission. [1] Optomechanical Cavity Cooling of an Atomic Ensemble M.H., Schleier-Smith, I.D. Leroux, H. Zhang, M.A. Van Camp, and V. Vuletić, Phys. Rev. Lett. 107, 143005 (2011)

Q 32.59 Wed 16:30 Spree-Palais

A CO_2-laser optical dipole trap with ultracold erbium atoms — •Jens Ulitzsch, Henning Brammer und Martin Weitz — Institut für Angewandte Physik, Wegelerstraße 8, 53115 Bonn

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

We report on progress in an ongoing experiment directed at the generation of an atomic Bose-Einstein condensate of erbium atoms in a quasistatic CO_2-laser optical dipole trap. Free erbium atoms are released from an effusive cell, precooled by a Zeeman-slower and trapped in a magneto-optical trap (MOT). Both Zeeman-slower and MOT use light of frequencies that are tuned to the red of the $400,91\,nm$ cooling transition. Atoms are then loaded into a quasistatic optical dipole trap generated by a focused CO_2-laser beam with a wavelength near $10,6\,\mu m$, and cooled evaporatively.

Successful loading of precooled erbium atoms from the MOT into the quasistatic optical dipole trap and first results for evaporative cooling will be shown.

Q 32.60 Wed 16:30 Spree-Palais

Cold atomic collisions of metastable Neon atoms — •Christian Cop and Reinhold Walser — TU Darmstadt, Institute of Applied Physics, Germany

In the group of G. Birkl, at the University of Darmstadt, the prospects to condense metastable neon atoms (Ne*) to degeneracy are investigated experimentally [1]. The major obstacle towards Bose-Einstein-Condensation of metastable noble gases is the high probability of Penning ionization, which hinders the process of effective evaporative cooling. This ionization process may be suppressed by spin polarization of the samples. For Ne*, the suppression of loss rates can be observed. Interestingly, the two stable bosonic isotopes ^{20}Ne* and ^{22}Ne* behave very differently. For ^{20}Ne*, the suppression ratio is an order of magnitude higher than for ^{22}Ne*.

For a theoretical description of the scattering physics of Ne* at cold and ultracold temperatures it is mandatory to account for quantum-statistical effects. We have adapted models including these effects [2] to a two-channel model which describes the process of Penning Ionization of Ne*. Solving the multi-channel Schrödinger equation for this model reproduces the measured differences between ^{20}Ne* and ^{22}Ne*. We present recent results and explanations.

[1] P. Spoden, M. Zinner, N. Herschbach, W. van Drunen, W. Ertmer, G. Birkl, Phys. Rev. Lett., 94, 223201 (2005)

[2] C. Orzel, M. Walhout, U. Sterr, P.S. Julienne, S.L. Rolston, Phys. Rev. A, 59, 1926 (1999)

Q 32.61 Wed 16:30 Spree-Palais

Optical analogue of a wire trap for neutral atoms — •Philipp Schneeweiss, Fam Le Kien, and Arno Rauschenbeutel — VCQ, TU Wien – Atominstitut, Stadionallee 2, 1020 Wien, Austria

We propose a trap for cold neutral atoms using a fictitious magnetic field induced by a nanofiber-guided light field [1]. In close analogy to magnetic side-guide wire traps realized with current-carrying wires, a trapping potential can be formed when applying a homogeneous magnetic bias field perpendicular to the fiber axis. We discuss this scheme in detail for laser-cooled cesium atoms and find trap depths and trap frequencies comparable to the two-color nanofiber-based trapping scheme [2] but with one order of magnitude lower powers of the trapping laser field. Moreover, the proposed scheme allows one to bring the atoms closer to the nanofiber surface, thereby enabling efficient optical interfacing of the atoms with additional light fields. Specifically, optical depths per atom of more than 0.4 are predicted, making this system a promising candidate for nanofiber-based nonlinear and quantum optics experiments.

[1] P. Schneeweiss *et al.*, New J. Phys., in press, arXiv:1308:4602
[2] E. Vetsch *et al.*, Phys. Rev. Lett. **104**, 203603 (2010).

Q 32.62 Wed 16:30 Spree-Palais

Optimization of guiding and trapping atomic beams on an atom chip — •Jan Mahnke[1], Ilka Geisel[1], Andreas Hüper[1], Kai Cordes[2], Wolfgang Ertmer[1], and Carsten Klempt[1] — [1]Institut für Quantenoptik, Leibniz Universität Hannover — [2]Institut für Informationsverarbeitung, Leibniz Universität Hannover

We investigate guiding and trapping of rubidium atoms on a mesoscopic chip structure with millimeter-scale wires. This structure is used to create a quadrupole field for a magneto-optical trap, a magnetic guide and a flexible magnetic trapping potential. With this setup, we are able to generate atomic beams with varying speed and temperature, as well as recapturing the launched atoms. These schemes usually require the control and timing of many mutually dependent currents, thus creating a wide range of experimental parameters. The optimization is a time-consuming task for a high-dimensional parameter space with unknown correlations.

Here we automate this process using a genetic algorithm based on Differential Evolution[1]. We find that this algorithm optimizes multiple correlated parameters and is robust against local maxima and experimental noise. The algorithm is flexible, easy to implement and finds better solutions than a manual search faster than existing methods. Especially atom chip experiments with their large sets of parameters, combined with short cycle times, highly benefit from an algorithm-based optimization. However, the proposed optimization is also applicable to a wide range of experimental setups.

[1] I. Geisel, Apll. Phys. Lett. 102, 214105 (2013)

Q 32.63 Wed 16:30 Spree-Palais

Interference Filter Stabilized ECDLs at Lithium D-Line Wavelength — •Tobias Eul, Jan Phieler, Benjamin Gänger, and Artur Widera — Technische Universität Kaiserslautern, FB Physik, Erwin-Schrödinger-Str. 46, 67663 Kaiserslautern, Germany

Laser cooling requires narrow linewidth laser sources with the possibility to precisely control the output wavelengths. Recently a diode laser design based on an interference filter stabilized linear cavity was introduced by X. Baillard et. al. [1].

Lasers based on this design have proven to provide superior stability and linewidth at a moderate cost realizing a simple and reliable alternative to the established standard Littrow configuration.

We report on the construction of such lasers operating at an emission wavelength of 671 nm, suitable for spectroscopy and laser cooling of Lithium atoms, and we present measurements of the beam characteristics.

[1] X. Baillard et. al., Opt. Commun. 266(2):609-613 (2006)

Q 32.64 Wed 16:30 Spree-Palais

Dynamics of ion zig-zag chains in a two dimensional double well — •Andrea Klumpp[1], Benno Liebchen[1], and Peter Schmelcher[1,2] — [1]Zentrum für Optische Quantentechnologien, Universität Hamburg, Luruper Chaussee 149, 22761 Hamburg — [2]The Hamburg Centre for Ultrafast Imaging, Luruper Chaussee 149, 22761 Hamburg

Ion traps are versatile tools for experiments in various fields, such as spectroscopy, quantum computing, molecular physics and biophysics [1]. Even though there is a large interest in the formation of various structures like ion crystals [2] or zig-zag configurations [3,4] the underlying dynamics are often not well understood. Here we investigate the dynamics of trapped ions in a two dimensional double well potential. The initial state of the ions in our setup is given by well separeted zigzag configurations in both wells. After quenching the barrier between the wells various structures including the formation of lines and partial revivals to the initial zig-zag configuration can be observed to alternate with phases of irregular motion in the course of the time evolution.

[1] Major, Gheorghe, Werth. Charged particle traps I+II Springer, (2005 + 2009)
[2] H. Landa et al., NJP 14 093023 (2012)
[3] A. del Campo et al. PRL 105,075701 (2010)
[4] M. Mielenz et al. PRL 110, 133004 (2013)

Q 32.65 Wed 16:30 Spree-Palais

Simultaneous D_1 line sub-Doppler laser cooling of fermionic ^{6}Li and ^{40}K – Experimental results and theory — •Mihail Rabinovic[1], Franz Sievers[1], Norman Kretzschmar[1], Diogo Fernandes[1], Daniel Suchet[1], Saijun Wu[2], Lev Khaykovich[3], Frédéric Chevy[1], and Christophe Salomon[1] — [1]Laboratoire Kastler Brossel, ENS/UPMC/CNRS, 75005 Paris, France — [2]Department of Physics, College of Science, Swansea University, Swansea, SA2 8PP., United Kingdom — [3]Department of Physics, Bar-Ilan University, 52900 Ramat-Gan, Israel

We report on simultaneous sub-Doppler laser cooling of fermionic ^{6}Li and ^{40}K on the D_1-transition. The D_1-molasses phase largely reduces the temperature for both ^{6}Li and ^{40}K, with a final temperature of $44\,\mu$K and $20\,\mu$K respectively. For both species this leads to a phase-space density close to 10^{-4} well suited to directly load an optical dipole trap.

We compare the experimental results to a numerical simulation of the cooling process using a semi-classical MonteCarlo wavefunction method and explore a potential application of D_1-cooling for ^{6}Li in a lattice trap.

In the context of laser cooling of ^{6}Li we present an all-solid-state laser source emitting 3.2 W of narrowband 671 nm light in a near-diffraction-limited beam. Our design is based on a diode-end-pumped Nd:YVO_4 ring laser operating at 1342 nm which is subsequently frequency doubled.

Q 32.66 Wed 16:30 Spree-Palais

Holographic detection approach for single-site detection of ultracold atoms in an optical lattice — •Daniel Hoffmann, Benjamin Deissler, and Johannes Hecker Denschlag — Institut für Quantenmaterie, Universität Ulm, Deutschland

Site-resolved imaging has recently been a key tool in studies of ultracold atoms in optical lattices. However, the large-NA optics and large photon scattering rates make this technique technically difficult to implement. Here, we present a holographic detection scheme, related to the classical Leith-Upatnieks technique, which enables a site-resolved detection of single atoms with a weak probe beam incident on the atoms and a strong reference beam. We discuss a possible detection setup and perform simulations on such a process. We show that the detection can be performed even with an incident laser intensity well below the saturation intensity of the atomic transition. Moreover, the detection scheme can be realized using only standard catalog lenses.

Q 32.67 Wed 16:30 Spree-Palais

Direct imaging of the momentum distribution of a two-dimensional quantum gas — •Puneet Murthy[1], Martin Ries[1], Mathias Neidig[1], Sebastian Pres[1], Dhruv Kedar[1], Andre Wenz[1], Gerhard Zürn[1], Thomas Lompe[2], and Selim Jochim[1] — [1]Physikalisches Institut, Heidelberg, Germany — [2]Massachusetts Institute of Technology, Cambridge, USA

We report a new technique to directly probe the in-situ radial momentum distribution of a 2D gas of ultracold atoms. After turning off the initial 2D confinement, which instantaneously switches off interactions, we let the gas evolve radially in a harmonic trap whereby the initial momentum distribution is mapped to the spatial distribution after a quarter of the trap period (T/4). However, the fast expansion of the 2D gas along the axial direction prohibits imaging at T/4 with sufficient resolution. We overcome this limitation by pulsing an optical harmonic potential, thereby significantly reducing the axial expansion, while keeping the gas dilute enough to prevent collisions.

Additionally, we propose a method to "zoom in" to the momentum distribution in a controlled manner. For this, we exploit the fact that atoms with opposite magnetic moments interact contrarily with magnetic field gradients. Thus, by sequentially transferring atoms between high-field and low-field seeking states, the initial momentum distribution can be mapped to a magnified spatial distribution. These two complementary techniques can be applied to a wide range of experiments involving 2D gases and will be particularly important to probing the many-body phases of quantum gases in 2D lattice potentials.

Q 32.68 Wed 16:30 Spree-Palais

Interaction of non-transversal light with nanofiber-trapped atoms — •Bernhard Albrecht, Christoph Clausen, Rudolf Mitsch, Daniel Reitz, Clement Sayrin, Philipp Schneeweiss, and Arno Rauschenbeutel — VCQ, TU Wien, Atominstitut, Stadionallee 2, A-1020 Wien, Austria

We recently demonstrated a nanofiber-based experimental platform for trapping and optically interfacing laser-cooled cesium atoms [1]. The scheme used allows us to confine the atoms in two diametric 1D arrays of traps located close to the nanofiber surface. The millisecond-long atomic ground state coherence times [2] and the good coupling of the trapped atoms to fiber-guided fields make this system a promising candidate as a future building block in a quantum optical network. Here, we experimentally investigate the opportunities for the manipulation of the trapped atoms when exploiting the non-transversal character of nanofiber-guided fields. We employ this effect to generate optically induced fictitious magnetic fields which render the two diametric arrays of trapped atoms energetically distinct, allowing us to selectively address the atoms on one side of the fiber. Moreover, using resonant fiber-guided fields, atoms can be optically pumped to opposite Zeeman states on the two sides of the fiber, creating two classes of atoms which are equally well coupled to a common optical mode. Combining these techniques opens the route towards atom-mediated directional channeling of light into the optical nanofiber.

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

Q 32.69 Wed 16:30 Spree-Palais

Excitation of the $^3\mathbf{P}_0$ clock transition in a Fermi gas of ytterbium — •Francesco Scazza[1,2], Christian Hofrichter[1,2], Moritz Höfer[1,2], Pieter C. de Groot[1,2], Christian Schweizer[1,2], Emily Davis[1,2], Immanuel Bloch[1,2], and Simon Fölling[1,2] — [1]MPI für Quantenoptik, Hans-Kopfermann-Straße 1, 85748 Garching, Germany — [2]Ludwig-Maximilians-Universität München, Schellingstraße 4, 80799 München, Germany

We report on the realization of a setup for probing the ultra-narrow $^3P_0$ clock transition of neutral ytterbium. In our setup we trap and cool a gas of fermionic ^{173}Yb atoms to the quantum degenerate regime.

The Fermi gas is loaded into an optical lattice operating at the magic wavelength of the ground and $^3P_0$ states. The coupling to the clock state is achieved by shining resonant narrow-linewidth laser light, obtained by stabilization to an ULE cavity reference.

Atomic population excitation with an absorption linewidth down to a few tens of Hertz was demonstrated. Rabi oscillations in a spin polarized gas indicate that this linewidth is limited by laser light coherence.

We report on spin state selective spectroscopy of the gas in a 3-dimensional lattice. Occupation number dependent shifts of the clock transition resonance were observed and characterized, as well as inelastic collisional processes involving the $^3P_0$ state.

Q 32.70 Wed 16:30 Spree-Palais

Investigating a single atom magneto optical trap — •Farina Kindermann, Michael Bauer, Tobias Lausch, Daniel Mayer, Felix Schmidt, and Artur Widera — FB Physik, TU Kaiserslautern Erwin Schrödinger Str. 46, 67663 Kaiserslautern

Single neutral atoms have proven ideal systems to study quantum effects on a microscopic level. In the last years, few or single impurity atoms have been a subject of intense study. Here we present our experimental setup to capture and detect single Cesium atoms as a first step towards impurity physics measurements. By means of fluorescence imaging with a high numerical aperture objective we count the number of atoms and observe MOT dynamics at the single atom level. We systematically investigate the effect of experimentally accessible parameters on signal-to-noise ratio or the atoms' temperature. In addition we investigate the limits of the assumption that atoms are independent, leading to the standard description of the MOT dynamics by Poissonian statistics.

Q 32.71 Wed 16:30 Spree-Palais

A high NA objective for two-dimensional discrete-time quantum walks — •Felix Kleissler, Stefan Brakhane, Carsten Robens, Stanislav Shestovy, Andrea Alberti, Wolfgang Alt, and Dieter Meschede — Rheinische Friedrich-Wilhelms Universität Bonn, Institut für Angewandte Physik

Recent advances in the detection and coherent manipulation of neutral atoms in single sites of optical lattices allow us to use quantum walks to simulate transport phenomena [1], where the physical information is extracted from the position of the atoms in the lattice.

Our planned apparatus features an in-house designed diffraction-limited high-numerical-aperture imaging system (NA = 0.92) with a spatial resolution of 500 nm. A characterization of the objective by a wavefront analysis and an evaluation of the point-spread function via imaging of a sub-micrometer pinhole will be presented.

First results on the realization of a two-color magneto-optical trap (MOT) working on the D1 and D2 line of Cs will be shown. This layout allows us to cool along the axis of the objective avoiding stray light in the fluorescence images [2].

The high NA objective in combination with a two color illumination are key ingredients to enable us to detect and address atoms down to the level of single lattice-sites in our 2D state-dependent lattice.

References: [1] M. Genske, W. Alt, A. Steffen, A. H. Werner, R. F. Werner, D. Meschede and A. Alberti, Phys. Rev. Lett. 110, 190601 (2013) [2] S. Wu, T. Plisson, R. C. Brown, W. D. Phillips, and J. V. Porto,Phys. Rev. Lett. 103, 173003 (2009)

Q 32.72 Wed 16:30 Spree-Palais

Flourescence imaging and sub-micrometer localization of a single atom strongly coupled to a cavity — •Ingmari Christa Tietje, Anna Caroline Eckl, Haytham Chibani, Christoph Hamsen, Paul Altin, Tatjana Wilk, and Gerhard Rempe — Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Straße 1, D-85748 Garching, Germany

A single two-level atom strongly coupled to a single mode of the electromagnetic field inside a Fabry-Perot cavity is a paradigm of fundamental matter-light interaction. To observe strong coupling we localized the atom in regions of high intensity with a standing-wave intra-cavity dipole trap and, in the past, evaluated only the photons escaping from the cavity.

We can now additionally image the atomic fluorescence light emitted into free-space to measure the atom's position along the cavity axis with a newly built imaging system. We obtain time-resolved sequences of images whose intensity distributions exhibit direct proof of strong coupling and its position dependence between atom and cavity along the standing-wave dipole trap. Counterintuitively, in regions of highest coupling strength g the rate of spontaneously emitted photons is lower than in regions of intermediate coupling strength. Moreover, we took movies of the atom hopping along the cavity axis.

Since the coupling strength g is position dependent, the movement of the atom effectively reduces g. To overcome this problem we now introduce a three-dimensional dipole trap which pins down the atom to the sub-micrometer level and localizes it well within the cavity mode.

Q 32.73 Wed 16:30 Spree-Palais

Accurate Mesoscopic Atom Counting in a Novel Hybrid Trap — •Ion Stroescu, David B. Hume, Wolfgang Muessel, Helmut Strobel, Daniel Linnemann, Jonas Schulz, and Markus K. Oberthaler — Kirchhoff-Institut für Physik, Universität Heidelberg, Im Neuenheimer Feld 227, 69120 Heidelberg, Germany

Many cold atom experiments rely on precise atom number detection, especially in the context of quantum-enhanced metrology where effects at the single particle level are important. We present the limits of state-selective atom number counting via resonant fluorescence detection for mesoscopic samples of magneto-optically trapped atoms. We characterize the precision of these fluorescence measurements and by investigating the primary noise sources, we obtain single-atom resolution for atom numbers as high as 1200.

With the addition of a blue-detuned light sheet barrier, we create a novel hybrid trap for neutral atoms, which allows us to extend our atom counting capabilities to two internal atomic states, for which we reach single-atom resolution for up to 500 particles in each state. This capability is an essential prerequisite for future experiments with highly entangled states of mesoscopic atomic ensembles.

Furthermore, the hybrid trap enables experimental access to the rate of light-assisted collisions in a strongly damped, dissipative system. We observe effects that are not explained by thermal reaction rate theory.

Finally, we show multiple signatures of a stochastic resonance in our system, including an increased signal-to-noise ratio for added thermal noise and a measurement of the phase lag of the non-linear response.

Q 32.74 Wed 16:30 Spree-Palais

Molecular dynamics of trapped cold gases on GPUs — •Roman Nolte and Reinhold Walser — Institut für Angewandte Physik, Technische Universität Darmstadt

The understanding of classical molecular dynamics of N rapped interacting atoms is an important precursor in order to achieve quantum degeneracy. In the QUANTUS experiment, which explores quantum gases in microgravity in the ZARM droptower in Bremen, the evaporation time is a scarce resource. It is therefore of critical importance to understand the non-equilibrium dynamics with high precision.

In this contribution we present results of N-particle 3D molecular dynamics simulation performed on graphic cards (GPU). We investigated the dependence of relaxation on external parameters and the validity of common assumptions.

Q 32.75 Wed 16:30 Spree-Palais

Dynamical Mean-Field Theory of Rydberg-dressed quantum gases in optical lattices — •Andreas Geissler, Ivana Vidanovic, and Walter Hofstetter — Goethe Universität, Frankfurt, Hessen

As recent experiments have shown, it is now possible to investigate Rydberg-dressed quantum systems in optical lattices with a large number of Rydberg excitations. Here we investigate these strongly correlated systems for the bosonic case, by applying the real-space extension of bosonic dynamical mean-field theory (R-BDMFT) to the two-species lattice Hamiltonian in two and three dimensions. We find new exotic quantum phases of lattice commensurate order, giving rise to a devil's staircase in the filling as a function of the chemical potential. For increased hopping, a nonzero condensate fraction starts to emerge, which can coexist with the spatial density order, and thereby lead to a supersolid phase. A rich phase diagram is obtained in our simulations for experimentally realistic parameters.

Q 32.76 Wed 16:30 Spree-Palais

Towards imaging of single Rydberg Atoms — •Vladislav Gavryusev, Georg Günter, Hanna Schempp, Martin Robert-de Saint-Vincent, Stephan Helmrich, Christoph S. Hofmann, Miguel Ferreira-Cao, Shannon Whitlock, and Matthias Weidemüller — Physikalisches Institut, Universität Heidelberg, Im Neuenheimer Feld 226, 69120 Heidelberg, Germany

Electronically highly excited (Rydberg) atoms constitute a system with long range interactions which allows to study many intriguing phenomena, ranging from quantum non-linear optics to dipole-mediated energy transport.

We demonstrate optical imaging of Rydberg atoms using the interaction enhanced imaging technique[1], which allows to follow spatially the evolution of the system. This method exploits interaction-induced shifts on highly polarizable excited states of probe atoms, that can be spatially resolved via an electromagnetically induced transparency resonance. With this novel tool we observe the migration of Rydberg electronic excitations, driven by quantum-state changing interactions similar to Förster processes found in complex molecules. We find that the many-body dynamics of the energy transport is influenced by the environment, controlled through the laser parameters[2]. After having improved the optical resolution and CCD detector, we are progressing towards the observation of individual Rydberg atoms which would allow to resolve the spatial and temporal dynamics of the system.

[1] G. Günter et al., Phys. Rev. Lett. 108, 013002 (2012)
[2] G. Günter et al., Science 342, 954 (2013)

Q 32.77 Wed 16:30 Spree-Palais

Atomic and photonic correlations in interacting Rydberg gases — •Miguel Ferreira-Cao, Vladislav Gavryusev, Georg Günter, Hanna Schempp, Martin Robert-de-Saint-Vincent, Christoph S. Hofmann, Shannon Whitlock, and Matthias Weidemüller — Physikalisches Institut, Universität Heidelberg, Im Neuenheimer Feld 226, 69120 Heidelberg, Germany

Ultracold atomic gases involving strongly interacting Rydberg states in combination with electromagnetically induced transparency provide an excellent system to generate nonclassical states of light [1,2].

Recent experiments have delivered evidence of effective photon-photon interactions and the corresponding atomic correlations [3,4]. Nonlocal effect such as self-focusing due to optical nonlinearities are predicted [5]. Strong antibunching of photons [2] as well as elastic interactions leading to bound state photons [6] are also evidenced.

We explore to which extent the emergence of photonic correlations can be related to atomic correlations through the full counting statistics of the Rydberg number [7] and direct Hanbury-Brown-Twiss measurements of photon correlations.

[1] Y. O. Dudin and A. Kuzmich, Science 336, 887 (2012)
[2] T. Peyronel et al., Nature 488, 57-60 (2012)
[3] D. Maxwell et al. Phys. Rev. Lett. 110, 103001 (2013)
[4] C.S. Hofmann et al., Phys. Rev. Lett. 110, 203601 (2013)
[5] S. Sevinçli et al. Phys. Rev. Lett. 107, 153001 (2011)
[6] O. Firstenberg et al., Nature 502, 71-75 (2013)
[7] H. Schempp et al. PRL accepted, arXiv:1308.0264 (2013)

Q 32.78 Wed 16:30 Spree-Palais

Artificial Abelian gauge potentials induced by dipole-dipole interactions between Rydberg atoms — •Alexandre Cesa and John Martin — Institut de Physique Nucléaire, Atomique et de Spectroscopie, Université de Liège, Bât. B15, B-4000 Liège, Belgium

We analyze the influence of dipole-dipole interactions between Rydberg atoms on the generation of Abelian artificial gauge potentials and fields. When two Rydberg atoms are driven by a uniform laser field, we show that the combined atom-atom and atom-field interactions give rise to nonuniform, artificial gauge potentials. We identify the mechanism responsible for the emergence of these gauge potentials. Analytical expressions for the latter indicate that the strongest artificial magnetic fields are reached in the regime intermediate between the dipole blockade regime and the regime in which the atoms are sufficiently far apart such that atom-light interaction dominates over atom-atom interactions. We discuss the differences and similarities of artificial gauge fields originating from resonant dipole-dipole and van der Waals interactions. We also give an estimation of experimentally attainable artificial magnetic fields resulting from this mechanism and we discuss their detection through the deflection of the atomic motion.

Q 32.79 Wed 16:30 Spree-Palais

Coherent Rydberg dynamics and interaction in thermal vapor cells — •Bernhard Huber, Andreas Kölle, Fabian Ripka, Robert Löw, and Tilman Pfau — 5. Physikalisches Institut, Uni Stuttgart

Rydberg atoms are of great interest due to their prospects in quantum information. Coherent control of the strong Rydberg-Rydberg interaction allows for the realization of quantum operations and devices which have been demonstrated in ultracold experiments. Since then, coherent dynamics to Rydberg states has been demonstrated also in thermal vapor cells on nanosecond timescales [1] and van der Waals interatomic interaction has been observed [2], where the interaction strength exceeds the energy scale of thermal motion and is thus strong enough to enable quantum correlations.

We present our progress on implementing a non-classical light source from a thermal vapor cell based on four-wave-mixing and Rydberg interaction.

We observe coherent dynamics within a thermal ensemble of Rydberg atoms in a pulsed four-wave-mixing scheme and effects of dephasing due to Rydberg-Rydberg interaction. Furthermore we discuss our recent work on the reduction of the excitation volume to below the Rydberg interaction range (few μm) in 3 dimensions by use of high-NA optics and spatial confinement. First results of Rydberg four-wave-mixing therein will be shown.

[1] Huber et al., PRL **107**, 243001 (2011)
[2] Baluktsian et al., PRL **110**, 123001 (2013)

Q 32.80 Wed 16:30 Spree-Palais

Rydberg-Rydberg interactions in high density caesium vapour — •Fabian Ripka[1], Alban Urvoy[1], Margarita Reschke[1], David Peter[2], Harald Kübler[1], Tilman Pfau[1], and Robert Löw[1] — [1]5. Physikalisches Institut, Universität Stuttgart, Pfaffenwaldring 57, 70550 Stuttgart Germany — [2]Institut für Theoretische Physik III, Universität Stuttgart, Pfaffenwaldring 57, 70550 Stuttgart Germany

Rydberg atoms are of growing interest, due to new physics provided by their exaggerated properties. For instance the van-der-Waals interaction between Rydberg atoms has been observed in thermal vapour [1] and is the foundation of several proposals for the realisation of quantum devices. It has also been demonstrated that a phase transition to collective behaviour of the Rydberg atoms can occur, leading to

superradiant decay to neighbouring Rydberg states [2].
We use the excitation scheme $6S_{1/2} - 7P_{3/2} - nS$, nD in caesium and focus on high densities (typ. 10^{12} to 10^{14} cm^{-3}), where these effects become relevant. We show a phase-transition-like behaviour between two types of excitation dynamics to the Rydberg state. The border between these two regimes lies at a critical detuning Δ_C, which depends on the experimental parameters (Rabi frequencies, atom number density, principal quantum number). One type of excitation dynamics is consistent with a two-body excitation process, while the other is of many-body nature. We also present first results on tailoring superradiant decay between Rydberg states by changing geometries.

[1] T. Baluktsian, B. Huber, et al., PRL **110**, 123001 (2013)
[2] C. Carr et al., PRL **111**, 113901 (2013)

Q 32.81 Wed 16:30 Spree-Palais

Energy transfer with long-range interactions — •Sebastian Weber, Robert Löw, and Sebastian Hofferberth — 5. Physikalisches Institut, Universität Stuttgart, Germany

Energy transport in quantum networks is of relevance to a wide range of systems. The most prominent example is the transport of light quanta in photosynthesis in light-harvesting complexes. Networks of Rydberg atoms are a highly promising system to study the energy transfer since the strong long-range Rydberg interaction can cause excitations to propagate.

Here, we present simulations of such systems. Our numerical implementation allows us to analyze arbitrary two-dimensional patterns coupled with nearest neighbor interaction or $1/R^{\alpha}$-potentials. We study how the propagation of excitations depends crucially on network geometry and interaction potentials. To gain a better understanding of phenomena observed, several dispersion relations are extracted from simulation data. A comparison with analytically calculated dispersion relations reveals finite-size effects. The analytic results are also used to validate the simulation program. Furthermore, we analyze the energy transfer between so-called superatoms. It becomes apparent that their physical extent causes dephasing.

Q 32.82 Wed 16:30 Spree-Palais

Ultracold Rydberg Gases in the Millisecond Regime — •Torsten Manthey, Thomas Niederprüm, Tobias Weber, Oliver Thomas, and Herwig Ott — Research Center Optimas, Technische Universität Kaiserslautern, 67663 Kaiserslautern,

We present our recent results measured with an apparatus, which is a combination of the scanning electron microscopy technique with a high power laser system for the single photon excitation to Rydberg states. We show that the electron beam is a powerful tool to prepare distributions of mesoscopic samples which are smaller than the dipole-dipole interaction induced blockade radius. These samples show an anti-bunching in the ion rate under illumination of the UV laser which is an evidence for the production of so-called superatoms. We furthermore demonstrate that the interactions between fast electrons and highly excited atoms is extremely large due to l-changing collisions.

Q 32.83 Wed 16:30 Spree-Palais

Optical control and detection of an ultracold Rydberg gas — •Peter Schauss[1], Johannes Zeiher[1], Sebastian Hild[1], Frauke Seesselberg[1], Takeshi Fukuhara[1], Marc Cheneau[2], Manuel Endres[1], Tommaso Macri[3], Thomas Pohl[3], Christian Gross[1], and Immanuel Bloch[1,4] — [1]Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Straße 1, 85748 Garching, Germany — [2]Laboratoire Charles Fabry - Institut d'Optique, Palaiseau, France — [3]Max-Planck-Institut für Physik komplexer Systeme, Nöthnitzer Straße 38, 01187 Dresden, Germany — [4]Fakultät für Physik, Ludwig-Maximilians-Universität München, Schellingstraße 4, 80799 München, Germany

Rydberg atoms open new perspectives for long-range correlated many-body states due to their strong van der Waals interactions. In our setup we optically excite Rydberg atoms and detect them with
submicron resolution, which allows us to measure spatial correlations of resulting ordered states.

The system sizes studied in experiment allow for high-accuracy simulation of the Rydberg Hamiltonian. Theoretical development of optimal adiabatic pulses and experimental studies can thus proceed side
by side, both profiting strongly from each other.

We will present our recent progress in detection and control of these finite Rydberg systems.

Q 32.84 Wed 16:30 Spree-Palais

Rydberg tomography of an ultra-cold atomic cloud — •María M. Valado[1,2], Nicola Malossi[1], Stefano Scotto[2], Donatella Ciampini[1,2,3], Ennio Arimondo[1,2,3], and Oliver Morsch[1] — [1]INO-CNR, Via G. Moruzzi 1, 56124 Pisa, Italy — [2]Dipartimento di Fisica E. Fermi, Università di Pisa, Largo Pontecorvo 3, 56127 Pisa, Italy — [3]CNISM UdR Pisa, Dipartimento di Fisica E. Fermi, Università di Pisa, Largo Pontecorvo 3, 56127 Pisa, Italy

One of the most striking features of the strong interactions between Rydberg atoms is the dipole blockade effect, whereby only a single excitation to the Rydberg state within the volume of the blockade sphere is allowed [1-4].

Here we present a method that spatially visualizes this phenomenon in an inhomogeneous gas of ultra-cold rubidium atoms. We scan the position of one of the excitation lasers across the cold cloud and determine the number of Rydberg excitations detected as a function of position. Comparing this distribution to the one obtained for the number of ions created by a two-photon ionization process via the intermediate 5P level, we demonstrate that the blockade effect modifies the width of the Rydberg excitation profile. Furthermore, we study the dynamics of the Rydberg excitation and find that the timescale for the excitation depends on the atomic density at the beam position[2, 3].

[1] Lukin et al., Phys. Rev. Lett. 87, 037901 (2001)
[2] Urban et al., Nature Phys.5, 110 (2009)
[3] Gaëtan et al., Nature Phys.5, 115 (2009)
[4] Comparat et al., J. Opt. Soc. Am. B 27, A208 (2010)

Q 32.85 Wed 16:30 Spree-Palais

Crystallization of photons via storage of interacting Rydberg polaritons — •Matthias Moos[1], Michael Höning[1], Johannes Otterbach[2], Dominik Muth[1], and Michael Fleischhauer[1] — [1]Fachbereich Physik und Forschungszentrum OPTIMAS, Technische Universität Kaiserslautern, 67663 Kaiserslautern, Germany — [2]Department of Physics, Harvard University, Cambridge, MA 02138, USA

The coupling of weak light fields to Rydberg states of atoms under conditions of electromagnetically induced transparency can be described in terms of Rydberg polaritons which have a tunable mass and strong nonlocal interactions, due to the van-der-Waals interactions of the atoms. Using exact wave-function calculations for two particles we show that after a short initialization time the physics is fully described by an effective many-body model of interacting Rydberg dark-state polaritons. Applying a time-dependent Luttinger liquid model we analyze the effect of the strong repulsive interactions on the storage of Photons into stationary Rydberg excitations. We show that the interactions lead to the generation of non-classical photon-states which exhibit crystalline order over a finite length.

Q 32.86 Wed 16:30 Spree-Palais

Large optical nonlinearities and single-photon switching using Rydberg Blockade — Simon Baur, •Daniel Tiarks, Gerhard Rempe, and Stephan Dürr — Max-Planck-Institut für Quantenoptik, 85748 Garching, Deutschland

Pairs of Rydberg atoms experience a large van-der-Waals interaction. Combining electromagnetically induced transparency with highly-lying Rydberg states creates a large optical nonlinearitiy at the single-photon level. We observe this nonlinearity as a saturation of the transmitted power as we increase the input power impinging on an ultra-cold gas of Rubidium atoms. The same nonlinearity causes antibunching that we observe in the pair-correlation function of the transmitted light. As an application, we implement an all-optical switch where a gate pulse changes the transmission of a subsequent target pulse. The gate pulse is stored in the medium and contains only one incoming photon on average. We further show that the stored light can be coherently retrieved after the target pulse passed the medium. Thus the coherence of the process is preserved and the switch might find applications in quantum information processing.

Q 32.87 Wed 16:30 Spree-Palais

Ultra stable laser system for two color photoassociation of Ca — •Max Kahmann[1], Evgenij Pachomow[1], Uwe Sterr[1], Fritz Riehle[1], and Eberhard Tiemann[2] — [1]Physikalisch Technische Bundesanstalt (PTB), Bundesallee 100, 38116 Braunschweig — [2]Institut für Quantenoptik, Welfengarten 1, 30167 Hannover

For manipulating the scattering length by optical Feshbach resonances (OFR) the small linewidth of ^{40}Ca (374 Hz) is expected to reduce the corresponding losses compared to the experiments with Yb and Sr [1].

We recently measured the binding energies of the least bound molecular states in the relevant molecular potentials [2]. These measurements and a derived coupled channel model for the atom pair asymptote $^1S_0+^3P_1$ indicate ^{40}Ca as a promising candidate for OFRs.
A variation of the scattering length by an OFR through a strong laser can be detected using a second laser for photoassociation to a more weakly bound state that probes the scattering wave function at larger atomic distances. The background scattering length can be determined by two-colour photoassociation spectroscopy of the least bound states in the ground state molecular potential applying the two ultrastable lasers. For these experiments two phase-locked ultra stable spectroscopy lasers were set up. As a first test we have applied the lasers for Bragg spectroscopy of the trapped atoms.
This work was funded by DFG through QUEST and RTG 1729.
[1] R. Ciurylo, E. Tiesinga, P. Julienne, PRA **71**, 030701 (2005)
[2] M. Kahmann et al, arXiv:1306.6473 (2013)

Q 32.88 Wed 16:30 Spree-Palais

A versatile transport apparatus for the production of ground-state YbRb — •Tobias Franzen, Cristian Bruni, Bastian Schepers, Kapilan Paramasivam, Christian Keller, Bastian Pollklesener, Markus Rosendahl, Ralf Stephan, and Axel Görlitz — Institut für Experimentalphysik, HHU Düsseldorf

Ultracold dipolar molecules constitute a promising system for the investigation of topics like ultracold chemistry, novel interactions in quantum gases, precision measurement and quantum information.

Here we report on the construction of a versatile transport apparatus for the production of ultracold YbRb molecules. This setup constitutes an improvement of our old apparatus, where the interactions in YbRb and possible routes to molecule production have already been studied extensively [1,2]. In the new setup a major goal is the efficient production of ground state YbRb molecules.

Separate production chambers allow the parallel production of Yb and Rb samples. Optical tweezers transport both species to a separate science chamber. This chamber provides excellent optical access and room for additional components in- and outside of the vacuum.
[1] F. Münchow et al., PCCP 13(42), 18734 (2011).
[2] M. Borkowski et al., Phys. Rev. A 88, 052708 (2013)

Q 32.89 Wed 16:30 Spree-Palais

Two-Photon-Spectroscopy of YbRb in a conservative trap - Towards paramagnetic molecules — •Cristian Bruni, Fabian Wolf, and Axel Görlitz — Institut für Experimentalphysik, HHU Düsseldorf, 40225 Düsseldorf

Ultracold heteronuclear molecules offer fascinating perspectives ranging from ultracold chemistry to novel interactions in quantum gases. In our experiment, the ultimate goal is the production of ultracold YbRb molecules in the electronic and rovibrational ground state. The special property of these molecules is that they possess a magnetic as well as an electric dipole moment. One- and and two-photon photoassociation spectroscopy close to the Rb D1-line at 795 nm was already performed in a combined MOT to study the vibrational levels in the electronic ground [1] and one excited state [2] of YbRb. In order to be able to create and trap the molecules these experiments have to be done in conservative traps. We use a magnetic trap for Rb and a near-resonant optical dipole trap for Yb red detuned to the $^1S_0$ to $^3P_1$ intercombination transition at 555.8 nm to simultaneously trap Rb and Yb. Here we report on the current status of our experiment.
[1] M. Borkowski et. al; Scattering lengths in isotopologues of the RbYb system, Phys. Rev. A 88, 052708 (2013)
[2] N. Nemitz, F. Baumer, F. Münchow and A. Görlitz, Phys. Rev. A 79, 061403(R) (2009)

Q 32.90 Wed 16:30 Spree-Palais

Towards ultracold polar NaK molecules — •Matthias W. Gempel, Torben A. Schulze, Torsten Hartmann, Janis Wöhler, Erik Schwanke, Julia Gerschmann, Alessandro Zenesini, and Silke Ospelkaus — Institut für Quantenoptik, Leibniz University Hannover, Germany

Quantum degenerate polar molecular are promising candidates for the study of strongly correlated quantum many-body systems. NaK represents a notable example for such studies, because of its large dipole moment of 2.72 Debye and because chemical reactions into homonuclear dimers are expected to be endothermic and therefore suppressed at ultra-cold temperature [PRA 81,060703(2010)]. Here, we present our progress towards quantum degenerate NaK molecules. In particular, we present theoretical studies resolving details of the molecular structure [PRA 88, 023401(2013)] as well as the current status of our experimental apparatus.