Q 25: Poster: Quantum Optics and Photonics I

Time: Tuesday 16:30–18:30 Location: S Atrium Informatik

Q 25.1 Tue 16:30 S Atrium Informatik

Unequal-time correlations in Bose-Einstein condensates — •Linda Shen[1,2] and Martin Gärttner[2] — [1]Institut für Theoretische Physik, Philosophenweg 16, 69120 Heidelberg, Germany — [2]Kirchhoff-Institut für Physik, Im Neuenheimer Feld 227, 69120 Heidelberg, Germany

We develop measurement schemes for unequal-time correlation functions in a Bose-Einstein condensate (BEC). Both the spectral and statistical components of the two-point correlation function are investigated out of equilibrium. Thereby, the time-evolution of a BEC is computed numerically using classical-statistical simulation methods based on the Gross-Pitaevskii equation.

The spectral correlation function is approached by linear response methods, which are in principle applicable to both numerical computations as well as experimental measurements. The statistical correlation function can be computed directly in the classical-statistical approximation. Extracting the unequal-time statistical function experimentally, however, requires involved techniques in order to avoid quantum back action effects. We propose to use a non-invasive measurement protocol where the system is weakly coupled to an ancillary system.

In thermal equilibrium, the spectral and statistical components are related by the fluctuation-dissipation theorem. Measuring both will allow a better understanding of how the fluctuation-dissipation theorem builds up as the system approaches equilibrium.

Q 25.2 Tue 16:30 S Atrium Informatik

Quantum Droplets with Tilted Dipoles — •Manuel Schmitt[1], Vladimir Veljić[2], Antun Balaž[2], and Axel Pelster[1] — [1]Research Center OPTIMAS and Department of Physics, Technische Universität Kaiserslautern, Germany — [2]Scientific Computing Laboratory, Center for the Study of Complex Systems, Institute of Physics Belgrade, University of Belgrade, Serbia

Since 2005 there have been many striking advancements in Bose-Einstein condensates (BECs) with dipolar interactions, the most recent one being the discovery of quantum droplets, which are stabilized due to quantum fluctuations [1, 2]. With a variational approach we investigate the influence of a tilted dipole axis on quantum droplets in a wave guide-like setup [3]. At first we generalize for one quantum droplet the energy functional for the extended Gross-Pitaevskii theory to tilted dipoles and determine the resulting deformation of the cloud as well as its stability as a function of the tilting angle. Furthermore, we consider two quantum droplets in a trap and calculate how their equilibrium distance depends on the tilting of the dipole axis. With this we gain new insight into the emergence of filaments of dipolar BECs.

[1] M. Schmitt et al., Nature **539**, 259 (2016)
[2] L. Chomaz et al., Phys. Rev. X **6**, 041039 (2016)
[3] I. Ferrier-Barbut et al., Phys. Rev. Lett. **116**, 215301 (2016)

Q 25.3 Tue 16:30 S Atrium Informatik

Many-body Multifractality in Fock space for Interacting Bosons — Jakob Lindinger, Andreas Buchleitner, and •Alberto Rodríguez — Physikalisches Institut, Albert-Ludwigs-Universität Freiburg, Hermann-Herder-Straße 3, D-79104 Freiburg, Germany

We analyse the many-body multifractality of the Bose-Hubbard Hamiltonian's eigenstates in Fock space, for arbitrary values of the interparticle interaction. For the ground state, generalized fractal dimensions unambiguously signal, even for small system sizes, the emergence of a Mott insulator. We show that the scaling of the derivative of any generalised fractal dimension with respect to the interaction strength encodes the critical point of the superfluid to Mott insulator transition, and we establish that the transition can be quantitatively characterized by one single wavefunction amplitude from the exponentially large Fock space [1]. Furthermore, multifractality of the excited eigenstates is investigated and the possible existence of localization in Fock space is thoroughly studied.

[1] J. Lindinger, A. Buchleitner, A. Rodríguez, arXiv:1810.06369

Q 25.4 Tue 16:30 S Atrium Informatik

Dynamics in multi-species bosonic systems — Tobias Brünner, •Gabriel Dufour, Alberto Rodríguez, and Andreas Buchleitner — Physikalisches Institut, Albert-Ludwigs-Universität Freiburg, Hermann-Herder-Straße 3, D-79104 Freiburg, Germany

The dynamics of bosons in multimode systems is determined by an involved interplay between interactions and indistinguishability-induced many-particle interference. We construct a formalism to investigate systematically the dynamics of multiple bosonic species, distinguishable by an internal degree of freedom which is insensitive to the time evolution. We unveil how interparticle interactions lead to a hierarchy of interaction-induced interference processes, such that even the dynamics of single-particle observables is influenced by the degree of indistinguishability (DOI). Time-averaged expectation values of observables dominated by two-particle interference are shown to correlate with a measure of the DOI for initial Fock states [1]. Time-resolved features of the dynamics, such as the frequency content of the signals, are also influenced by the DOI and reveal the interacting or non-interacting nature of the system. We show that this can be understood from the symmetry properties of the Hamiltonian based on group-theoretical arguments [2].

[1] T. Brünner, G. Dufour, A. Rodríguez, A. Buchleitner, Phys. Rev. Lett. 120, 210401 (2018)
[2] T. Brünner, PhD Thesis, Albert-Ludwigs-Universität Freiburg (2018). https://doi.org/10.6094/UNIFR/16683

Q 25.5 Tue 16:30 S Atrium Informatik

Rotational cooling of molecules in a BEC — •Martin Will, Tobias Lausch, and Michael Fleischhauer — University of Kaiserslautern, 67663 Kaiserslautern, Germany

We discuss the rotational cooling of homonuclear diatomic molecules in a Bose-Einstein-condensate (BEC) . For typical molecules there is no frictionless rotation since the dominant cooling occurs via emission of particle-like phonons. Only for macro-dimers, whose size becomes larger than the condensate healing length, a Landau-like, critical angular momentum exists below which phonon emission is suppressed. We find that the phonon-induced angular momentum relaxation is much faster than the cooling of linear motion of impurities in a BEC. This also leads to a finite lifetime of angulons, quasi-particles of rotating molecules coupled to orbital angular-momentum phonons. The lifetimes are however still smaller than typical angulon binding energies. We analyze the dynamics of rotational cooling for homo-nuclear diatomic molecules based on a quantum Boltzmann equation including single- and two-phonon scattering and discuss the effect of thermal phonons. For typical molecules two-phonon scattering becomes relevant at finite temperature.

Q 25.6 Tue 16:30 S Atrium Informatik

Coexistence of phase transitions and hysteresis near the onset of Bose-Einstein condensation — Michael Maennel[3] and •Klaus Morawetz[1,2] — [1]Münster University of Applied Sciences,Stegerwaldstrasse 39, 48565 Steinfurt, Germany — [2]International Institute of Physics- UFRN,Campus Universitário Lagoa nova,59078-970 Natal, Brazil — [3]Informatik DV,Petersstr. 14,04109 Leipzig, Germany

Multiple phases occurring in a Bose gas with finite-range interaction are investigated [2]. In the vicinity of the onset of Bose-Einstein condensation (BEC), the chemical potential and the pressure show a van der Waals-like behavior indicating a first-order phase transition for weak interactions like Hartree-Fock or Popov approximation. However, for strong interactions there remains a multivalued region for the T-matrix approximation even after the Maxwell construction, which is interpreted as a density hysteresis [1]. This unified treatment of normal and condensed phases becomes possible due to the recently found scheme to eliminate self-interactions in the T-matrix approximation, which allows one to calculate properties below and above the critical temperature [3,4]. [1] Phys. Rev. A 87 (2013) 053617, [2] New J. Phys. 12 (2010) 033013, [3] J. Stat. Phys. 143 (2011) 482, [4] Phys. Rev. B 84 (2011) 094529

Q 25.7 Tue 16:30 S Atrium Informatik

Dynamics of weakly interacting bosons in optical lattices with flux — •Ana Hudomal[1], Ivana Vasić[1], Hrvoje Buljan[2], Walter Hofstetter[3], and Antun Balaž[1] — [1]Scientific Computing Laboratory, Center for the Study of Complex Systems, Institute of Physics

Belgrade, University of Belgrade, Serbia — [2]Department of Physics, Faculty of Science, University of Zagreb, Croatia — [3]Institut für Theoretische Physik, Johann Wolfgang Goethe-Universität, Frankfurt am Main, Germany

Realization of strong synthetic magnetic fields in driven optical lattices has enabled implementation of topological bands in cold-atom setups [1,2]. A milestone has been reached by a recent measurement of a finite Chern number based on the dynamics of incoherent bosonic atoms [2]. Motivated by these recent developments, we investigate the dynamics of weakly interacting incoherent bosons in a two-dimensional driven optical lattice exposed to an external force, which provides a direct probe of the Chern number [3]. We find that interactions lead to the redistribution of atoms over topological bands both through the conversion of interaction energy into kinetic energy during the expansion of the atomic cloud and due to an additional heating. Remarkably, we observe that the moderate atomic repulsion facilitates the measurement by flattening the distribution of atoms in the quasimomentum space.

[1] G. Jotzu et al., Nature **515**, 237 (2014).
[2] M. Aidelsburger et al., Nature Phys. **11**, 162 (2015).
[3] A. Hudomal et al., Phys. Rev. A **98**, 053625 (2018).

Q 25.8 Tue 16:30 S Atrium Informatik

Quench dynamics and boundary condition dependence of the one-dimensional extended Bose Hubbard model — •Sebastian Stumper, Junichi Okamoto, and Michael Thoss — Insitute of Physics, University of Freiburg, Freiburg, Germany

The one-dimensional extended Bose Hubbard model exhibits a variety of quantum phases due to its competing interactions. For large on-site interactions, a Mott insulating (MI) phase exists, while a charge density wave (CDW) phase becomes dominant for large nearest-neighbour interactions. In between these phases, there exists a topologically nontrivial phase of a Haldane insulator (HI), which is characterized by a non-local string order (Phys. Rev. Lett. 97, 260401 (2006)). Ground state properties and low energy spectra are, however, very sensitive to the treatment of boundary conditions (arXiv:1403.2315 (2014)). We study an open chain of the extended Bose Hubbard model for various configurations of chemical potentials applied at the edges using the density matrix renormalization group method (Comput. Phys. Commun. 225, 59 (2018)). Without edge potentials, the CDW and HI phases show a non-degenerate ground state, and the order parameters change signs in the middle of the chain. This feature is robust against finite size scaling and is explained by a simple effective picture for the low energy states. On the other hand, with large edge potentials, the sign change of the order parameters disappears, and we recover uniform bulk ground states. Furthermore, we simulate quenched dynamics with initial states from MI, HI and CDW phases and discuss the results in terms of our findings on the equilibrium cases.

Q 25.9 Tue 16:30 S Atrium Informatik

Staggered-immersion cooling of a quantum gas in optical lattices — •Bing Yang[1,2,3], Hui Sun[1,2,3], Chun-jiong Huang[2,3], Han-yi Wang[1,2,3], You-jin Deng[2,3], Han-ning Dai[1,2,3], Zhen-sheng Yuan[1,2,3], and Jian-wei Pan[1,2,3] — [1]Physikalisches Institut, Ruprecht-Karls-Universität Heidelberg, Im Neuenheimer Feld 226, 69120 Heidelberg, Germany — [2]Hefei National Laboratory for Physical Sciences at Microscale and Department of Modern Physics, University of Science and Technology of China, Hefei, Anhui 230026, China — [3]CAS Centre for Excellence and Synergetic Innovation Centre in Quantum Information and Quantum Physics, University of Science and Technology of China, Hefei, Anhui 230026, China

Here we realize efficient cooling of ten thousand ultracold bosons in staggered optical lattices. By immersing Mott-insulator samples into removable superfluid reservoirs, thermal entropy is extracted from the system. Losing less than half of the atoms, we lower the entropy of a Mott insulator by 65-fold, achieving a record-low entropy per particle of 0.0019 k_B (k_B is the Boltzmann constant). We further engineer the sample to a defect-free array of isolated single atoms and successfully transfer it into a coherent many-body state. The present staggered-immersion cooling opens up an avenue for exploring novel quantum matters and promises practical applications in quantum information science.

Q 25.10 Tue 16:30 S Atrium Informatik

Simulation of the Quantum Rabi Model with Ultracold Rubidium Atoms in the Deep Strong Coupling Regime — •Geram Hunanyan[1], Johannes Koch[1], Martin Leder[1], Enrique Rico[2,3], Carlos Sabin[4], Enrique Solano[2,3], and Martin Weitz[1] — [1]Institut für Angewandte Physik Bonn, Wegelerstr. 8, D-53115 Bonn, Germany — [2]Department of Physical Chemistry, University of the Basque Country UPV/EHU, Apartado 644, E-48080 Bilbao, Spain — [3]IKERBASQUE, Basque Foundation for Science, Maria Diaz de Haro 3, E-48013 Bilbao, Spain — [4]Instituto de Fisica Fundamental, CSIC, Serrano 113-bis, E-28006 Madrid, Spain

The Quantum Rabi Model (QRM) has been applied to describe the dynamics of a two-level quantum system interacting with a single bosonic mode. Although a fair quantity of experiments explore the strong coupling regime of the QRM, where due to the still limited coupling strength the system can be transformed to the widely known Jaynes-Cummings Model, researchers are just beginning to exploit the regime where the full QRM must be considered. Our experimental implementation to simulate the QRM uses ultracold rubidium atoms in an optical lattice potential, with the effective two-level quantum system being simulated by different Bloch bands in the first Brillouin zone. The bosonic mode is represented by the oscillations of the atoms in an optical dipole trapping potential. We experimentally observe the atomic dynamics in the deep strong coupling regime. The present status of results will be presented.

Q 25.11 Tue 16:30 S Atrium Informatik

Probing the mott-insulator state in optical lattices with photoassociation collisions — •Hui Sun, Bing Yang, Zhen-sheng Yuan, and Jian-wei Pan — Physikalisches Institut, Ruprecht-Karls-Universität Heidelberg, Im Neuenheimer Feld 226, 69120 Heidelberg, Germany

The photoassociation collision is a process two colliding atoms form an excited molecular state after absorbing a photon, which can be used to remove doublons in optical lattices. In this work, we present the detection of a bosonic Mott-insulator state in optical lattices via photoassociation collisions. The photoassociation frequency and collision strength in the 0_g^- molecular channel are calibrated in ultracold quantum gases of Rb^{87}. Then we measure the density distributions of two-dimensional Mott-insulator states in optical lattices after illuminated by a photoassociation light, which is 13.6 cm^{-1} red detuned to the D2 line. From the density profiles, we extract the temperatures of the Mott-insulators and demonstrate an improvement of the measurement precision. This new method extends our ability to probe this ultracold strongly correlated systems.

Q 25.12 Tue 16:30 S Atrium Informatik

Probing Equilibration of Isolated Quantum Systems in a Spinor Bose-Einstein Condensate — •Stefan Lannig, Rodrigo Rosa-Medina Pimentel, Maximilian Prüfer, Philipp Kunkel, Alexis Bonnin, Helmut Strobel, and Markus K. Oberthaler — Kirchhoff-Institut für Physik, Im Neuenheimer Feld 227, 69120 Heidelberg

If and how isolated quantum systems eventually reach thermal equilibrium is still an open question. To address this we experimentally investigate the spin dynamics of a Bose-Einstein condensate of ^{87}Rb. In particular, we focus on the long-time dynamics in the $F = 1$ hyperfine manifold, which realises a spin-1 system. We prepare the system in different out-of-equilibrium states and probe its subsequent evolution by applying a new readout technique which allows to simultaneously extract multiple spin projections. We observe that the kinetic temperature, leading to a finite non-condensed fraction, impacts the coherent evolution and relaxation of the spin observables.

Using local control of the spin orientation and atomic density we aim at further exploring and understanding the relaxation processes involved in the temporal evolution of a 1-d spinor system. We investigate the response of the system to controlled local perturbations which can be connected to spatial and temporal correlations offering new observables for characterisation of general many-particle quantum dynamics.

Q 25.13 Tue 16:30 S Atrium Informatik

Non-equilibrium dynamics of interacting Bosons in an optical lattice — •Jens Benary[1], Christian Baals[1,2], Jian Jiang[1], and Herwig Ott[1] — [1]Department of Physics and OPTIMAS research center, Technische Universität Kaiserslautern, 67663 Kaiserslautern, Germany — [2]Graduate School Materials Science in Mainz, 55128 Mainz, Germany

We study the non-equilibrium dynamics of ultracold Bose gases using a scanning electron microscope. In our latest setup an optical system is used to map arbitrary intensity distributions created by a digital micro mirror device onto a Bose-Einstein condensate. The objective is to create grey solitons or vortices by imprinting a phase profile on a cigar-shaped condensate. The dynamics of these solitons/vortices in the presence of dissipation induced by an electron beam are investigated. We present latest results as well as a new setup.

Q 25.14 Tue 16:30 S Atrium Informatik

Vortices and droplets in dipolar Bose-Einstein condensates — •Antun Balaž[1] and Axel Pelster[2] — [1]Scientific Computing Laboratory, Center for the Study of Complex Systems, Institute of Physics Belgrade, University of Belgrade, Serbia — [2]Research Center OPTIMAS and Department of Physics, Technische Universität Kaiserslautern, Germany

In the recent experiment [1], the Rosensweig instability was observed in a quantum ferrofluid of a strongly dipolar BEC, leading to a formation of atomic droplets, which represent a new state of quantum matter. In Ref. [2-4] it was demonstrated that the stability of such droplets is due to a quantum fluctuation correction of the ground-state energy [5-7]. Here we extend this previous theoretical description and develop a full Bogoliubov-Popov theory, which also takes into account the condensate depletion due to quantum fluctuations. We apply this approach and use extensive numerical simulations to study both the formation and the properties of vortices in a rotating ^{164}Dy BEC, including the droplet phase.

[1] H. Kadau, et al., Nature **530**, 194 (2016).
[2] F. Wächtler and L. Santos, Phys. Rev. A **93**, 061603(R) (2016).
[3] F. Wächtler and L. Santos, Phys. Rev. A **94**, 043618 (2016).
[4] L. Chomaz, et al., Phys. Rev. X **6**, 041039 (2016).
[5] T. D. Lee, K. Huang, and C. N. Yang, Phys. Rev. **106**, 1135 (1957).
[6] A. R. P. Lima and A. Pelster, Phys. Rev. A **84**, 041604(R) (2011).
[7] A. R. P. Lima and A. Pelster, Phys. Rev. A **86**, 063609 (2012).

Q 25.15 Tue 16:30 S Atrium Informatik

Bose-Einstein condensation in higher Bloch bands of a honeycomb optical lattice — •Tobias Klafka, Alexander Ilin, Julius Seeger, Mario Neundorf, Klaus Sengstock, and Juliette Simonet — Institut für Laserphysik, Universität Hamburg, Luruper Chaussee 149, 22761 Hamburg

Bose-Einstein condensates in higher Bloch bands of optical lattices immensely extend the possibilities for quantum simulation of solid-state models by providing new orbital degrees of freedom. In combination with appropriate lattice symmetries these orbital optical lattices give rise to unconventional superfluids with exotic properties. Here, we report on Bose-Einstein condensation in the second Bloch band of a honeycomb optical lattice realized by dynamically tuning the energy offset between the two sublattices. We have investigated the process of recondensation and optimal transfer tracing the dynamics in the Brillouin zones after the initial excitation. In addition, our preparation technique allows us to efficiently transfer superfluids into even higher Bloch bands where unexplored topological quantum phases shall emerge.

Q 25.16 Tue 16:30 S Atrium Informatik

Laser using narrow band intercombination line of Calcium — •Torben Laske, Hannes Winter, and Andreas Hemmerich — Institut für Laserphysik

We present our setup for realizing a superradiant laser [1] similar to the proposal to [2] using the narrow Calcium intercombination line $4^1S_0 \leftrightarrow 4^3P_1$ as the laser transition. Such a laser operates in the bad-cavity regime, in which the coherence is not stored in the intra cavity light field but in the gain medium. We are able to prepare a pure ensemble of $^3P_1$-Atoms (i.e. full inversion) trapped inside the cavity mode. By measuring the subsequent photon emission rate behind the cavity, we analyze the atomic decay. The observation of smaller decay times (76 μs) than the natural lifetime of the $^3P_1$ state (431 μs) is an indication for superradiance.

[1] M. Holland and J. Thompson et al. Nature, 484(7392):78-81, (2012). [2] M. Holland et al., Phys. Rev. Lett. 102(16):163601, (2009).

Q 25.17 Tue 16:30 S Atrium Informatik

Measuring symmetry protected Wilson lines — •Christoph Braun[1,2], Karen Wintersperger[1,2], Jakob Näger[1,2], Immanuel Bloch[1,2], and Monika Aidelsburger[1,2] — [1]Ludwig-Maximilians-Universität, Schellingstraße 4, 80799 München, Germany — [2]Max-Planck-Institut für Quantenoptik, Hans-Kopfermann Straße 1, 85748 Garching, Germany

Utilizing ultracold ^{39}K in an optical honeycomb potential we study the geometric properties of the two lowest energy bands.

Rapid lattice acceleration introduces an energy scale that redners the lowest two bands effectively degenerate [1]. In this regime the evolution during transport is goverened purely by the geometry of the underlying lattice and is described by a dispersion-independent Wilson line. For certain paths in momentum space featuring the symmetry of the lattice, the Wilson line eigenvalues remain fixed to 3rd roots of unity even away from the atomic limit [2]. By deforming the lattice we study how different broken symmetries modify the eigenvalues of the respective Wilson lines.

[1] T. Li, et al., Science 352, 1094 (2016).
[2] J. Höller and A. Alexandradinata, Phys. Rev. B 98, 024310 (2018).

Q 25.18 Tue 16:30 S Atrium Informatik

Bloch oscillations in higher bands of an optical lattice — •José Vargas, Carl Hippler, and Andreas Hemmerich — Institut fuer Laserphysik, Universitaet Hamburg, Luruper Chaussee 149, 22761 Hamburg

The overall goal of our experiment is to explore ultracold bosonic quantum gases in excited bands of an optical lattice. We investigate ^{87}Rb atoms in a bipartite interferometric 2D-lattice which allows us to change the lattice geometry dynamically. We report the observation of Bloch oscillation in the first, the second as well as the forth band of the optical lattice.

Q 25.19 Tue 16:30 S Atrium Informatik

A tunable quantum gas for the study of universal time dynamics far from equilibrium — •Maurus Hans, Celia Viermann, Helmut Strobel, and Markus K. Oberthaler — Kirchhoff-Institut für Physik, Universität Heidelberg, Deutschland

Degenerate quantum gases offer a particularly isolated setting to study the relaxation of quantum many-body systems initialised far from equilibrium. For many scenarios it is desirable to control the atomic interactions over a wide range. For this, a ^{39}K Bose-Einstein condensate is a promising experimental system as it exhibits broad magnetic Feshbach resonances for the tuning of the scattering length.

We give an overview of our experimental setup including the implementation of gray molasses sub-Doppler cooling and all-optical evaporation to Bose-Einstein condensation. Furthermore, we present first observations of far from equilibrium dynamics.

Q 25.20 Tue 16:30 S Atrium Informatik

Lifetime of a chiral superfluid in an orbital optical lattice — •Max Hachmann[1], Raphael Eichberger[1,2], Robert Büchner[1], and Andreas Hemmerich[1,2] — [1]Institut für Laserphysik — [2]The Hamburg Center for Ultrafast Imaging

We study bosons in metastable higher bands of an optical square lattice, where the composition of local orbitals with different nodal geometry and orientation can lead to wavefunctions with highly complex patterns of the local phase. In the second band the ground state wavefunction comprises local p_x and p_y-orbitals. If the lattice beams are precisely controlled to provide 4-fold rotation symmetry, p_x and p_y-orbitals are degenerate and repulsive interaction favors a complex superposition $p_x \pm ip_y$. Hence, a complex wavefunction arises with a staggered vortex phase pattern. If due to lattice imperfections a small energy difference on the order of several nanokelvin of p_x and p_y-orbitals is adjusted, only the energetically lower of the p-orbitals is populated and a real striped phase pattern arises. We present a novel optical lattice setup, which utilizes a Michelson-Sagnac interferometer. It enables the excitation to higher bands and a precise control of even fine details of the bandstructure. The lifetime of excited metastable states in higher bands is limited by binary collisions and depends sensitively on the details of the band structure. Close to $p_x \pm ip_y$-order the lifetime is expected to signiffcantly increase due to negative interference of different relaxation channels. We report first measurements demonstrating this effect.

Q 25.21 Tue 16:30 S Atrium Informatik

The simulation of phase trasnsion from spin-mott to xy-ferromagnatic — •Hanyi Wang — Physikalisches Institut, Ruprecht-Karls-Universität Heidelberg, Im Neuenheimer Feld 226, 69120 Heidelberg, Germany

We simulate a two-component Bose-Hubbard model in 1D optical lattice with density matrix renormalization group method.We start from a spin-mott phase,where each site is occupied by one spin-up and one spin-down atom.By adiabaticaliy ramping down the spin-dependent lattice, the spin mott phase can transfer to xy-ferromagnetic phase .We calculate the Luttinger parameter using the exponential relationship between the magnetic correlation function and the associated length.And then phase-transition point is estimated.We get the phase diagram by mappng all the phase-transition point.

Q 25.22 Tue 16:30 S Atrium Informatik

An experiment for the study of small Hubbard models with rapid repetition rate — Martin Schlederer, Phillip Wieburg, •Alexandra Mozdzen, Thomas Lompe, and Henning Moritz — Institut für Laserphysik, Universität Hamburg, Hamburg, Deutschland

Investigating the Fermi-Hubbard model with cold atoms is typically done by evaporatively cooling an ultracold Fermi gas and loading it into a large optical lattice. In contrast, we plan to assemble small Fermi-Hubbard type systems site by site using optical microtraps. Each microtrap will contain a single atom cooled to the vibrational ground state by Raman-sideband cooling [1]. This technique combines fast experimental cycle times with single site addressability and detection and will allow to study the fundamental processes governing the Fermi-Hubbard model in a bottom-up approach.

The poster will present the current status of the experiment: We trap 40K atoms in a magneto-optical trap and cool them to sub-Doppler temperatures using a gray molasses. After magnetic transport to the science region they are loaded into an optical microtrap where Raman-sideband cooling is performed and currently optimized. In the next step the atoms will be loaded into flexible configurations of microtraps. In order to create those microtraps as well as to manipulate the trapped atoms individually, we use two high resolution microscopes objectives located inside the vacuum chamber.

[1] A.M. Kaufman et al., Physical Review X 2, 041014 (2012).

Q 25.23 Tue 16:30 S Atrium Informatik

Topological light-matter defects as low-lying excitations of 1D optical atom-traps — •Kieran Fraser and Francesco Piazza — Max-Planck Institute for the Physics of Complex Systems

We consider laser-driven neutral fermionic atoms coupled to the electromagnetic modes of a multimode optical waveguide. In the presence of a sharp Fermi surface in one spatial dimension, the system's steady state spontaneously breaks translation invariance to form one of two possible dimerized crystalline patterns of atoms and light. Here we demonstrate that the low-lying excitations of this insulating phase are optical solitons with a size set by the inverse Fermi momentum creating a domain wall between two regions of opposite dimerization. Each defect is characterized by a Z2 topological quantum number and traps a fermion in an edge state. In a specific parameter regime that we identify, these hybrid light-matter defects are formally equivalent to those appearing in electron-phonon models. We propose optical transmission spectroscopy using waveguide modes as a means to non-destructively detect the defects. Some extensions to a driven-dissipative setup are considered.

Q 25.24 Tue 16:30 S Atrium Informatik

Towards ultra-low entropy quantum states in the Fermi-Hubbard model — •Justus Brüggenjürgen, Muqing Xu, Geoffrey Ji, Christie Chiu, and Markus Greiner — Department of Physics, Harvard University, Cambridge, Massachusetts 02138, USA

Quantum gas microscopy of fermionic atoms enables site-resolved studies of strongly correlated quantum many-body states in the Fermi-Hubbard Model. The addition of entropy redistribution via a digital micromirror device (DMD) has allowed us to achieve sufficiently low temperatures for long-range antiferromagnetic order. To reach even lower temperatures and address long-standing open questions of the repulsive Fermi-Hubbard model, new techniques for quantum state preparation are required. In particular, we have created ultra-low entropy band insulators as a starting point to adiabatically realize ultra-low entropy many-body states. To perform this adiabatic ramp, we are developing a low-noise interfering lattice, which enables dynamic tunability of the lattice geometry. Such a setup can also be used for other applications, including simultaneous readout of both spin species. I will discuss our progress towards ultra-low entropy quantum state preparation with interfering lattices.

Q 25.25 Tue 16:30 S Atrium Informatik

Analytical tailor-made optical potentials using a phase-only Spatial Light Modulator (SLM) — •Tobias Hammel, Lukas Palm, Philipp Preiss, and Selim Jochim — Physikalisches Institut, University of Heidelberg, Germany

One of the main tasks in quantum simulations with cold atoms is engineering the Hamiltonian of interest. To this end, SLMs have been shown to be particularly useful tools for the generation of high-quality, arbitrary light fields.

In this poster we show an analytic approach for the calculation of the required holograms on the SLM to get the desired optical potential in the atom plane. Because every optical setup adds unwanted phase aberrations onto the beam we discuss numerical ways to correct for those phase aberrations and measure the residual aberrations of the wave fronts to be of the order of one percent of the wavelength. Furthermore we show a way to correct for non-uniform illumination of the SLM chip caused by the Gaussian envelope of the incident light field and quantify the resulting uniformity of the beam amplitude.

In our setup we use an Amplified Spontaneous Emission (ASE) light source at 1064 nm with a coherence length of about 1mm. This prevents reflections from interfering with the trapping potential and reduces unwanted fringing. We can thus increase the quality of the programmable atom traps.

Those improvements will help to realize various physical systems, for example Quantum Hall states in few fermion systems.

Q 25.26 Tue 16:30 S Atrium Informatik

Production of quantum degenerate Bose-Fermi mixtures of ^{6}Li and ^{133}Cs — •Binh Tran[1], Manuel Gerken[1], Markus Neiczer[1], Eleonora Lippi[1], Lauritz Klaus[1], Bing Zhu[1,2], and Matthias Weidemüller[1,2] — [1]Physikalisches Institut, Universität Heidelberg, Im Neuenheimer Feld 226, 69120 Heidelberg, Germany — [2]Shanghai Branch, University of Science and Technology of China, Shanghai 201315, China

The ^{6}Li-^{133}Cs system is particularly well-suited for studying impurity physics since it offers the largest mass ratio among stable alkali atoms. Besides the tunability of attractive and repulsive interactions, the Li-Cs Feshbach resonances allow for the preparation of stable Bose and Fermi polarons, where an impurity is dressed by the elementary excitations of a Bose-Einstein condensate or a Fermi sea, respectively. We describe the production of a ^{133}Cs Bose-Einstein condensate by means of degenerate Raman sideband cooling and subsequent forced evaporative cooling. Furthermore, we describe the creation of a degenerate Fermi gas by performing gray-molasses cooling after which we load the sample into a flexible optical dipole trap involving a time-averaged optical potential. The latter offers good starting conditions for further evaporative cooling. Eventually, we discuss possibilites to cancel the gravitational sag and combine both species in order to study polaron physics or to create double degenerate mixtures.

Q 25.27 Tue 16:30 S Atrium Informatik

Dynamics of homogeneous Fermi gases in arbitrary potentials — •Lennart Sobirey, Niclas Luick, Markus Bohlen, Bernd Lienau, Thomas Lompe, and Henning Moritz — Institut für Laserphysik, Universität Hamburg, Deutschland

Ultracold Fermi gases in highly anisotropic traps have recently become available as versatile tools for studying the many-body physics of strongly interacting twodimensional (2D) many-body systems. Here, we present our experimental realisation of a homogeneous 2D Fermi gas, trapped in arbitrary potentials generated by spatial light modulators (SLM). Using multiple SLMs, we can generate precisely tailored potential landscapes and study excitations. We demonstrate how this technique can be used to create quantum gas analogues to systems from solid state physics and show first results on the dynamics of superfluids in tailored potentials.

Q 25.28 Tue 16:30 S Atrium Informatik

Towards an experimental implementation of topological interfaces and chiral edge modes for fermions in an optical lattice — •Sandra Buob, Michael Messer, Frederik Görg, Kilian Sandholzer, Joaquín Minguzzi, Konrad Viebahn, Rémi Desbuquois, and Tilman Esslinger — Institute for Quantum Electronics, ETH Zürich, Zürich, Switzerland

Chiral edge modes are known from the quantum Hall effect where they emerge along the boundary at the edge of a sample. In general, they are related to interfaces between distinct topological regions. The creation of such topological interfaces in an optical-lattice realization of the Haldane model for cold atoms has been proposed by N. Goldman et al. (Phys. Rev. A **94**, 043611 (2016)). In this proposal, interfering laser beams together with a near commensurate beam form a superlattice potential with a linear varying site offset across the confined atomic cloud. At a critical site offset, a topological interface forms and induces edge modes, which can be controlled in position, localization length and chirality. Here, we present the detailed setup of the dual laser system with tunable relative frequency. In addition, we show characterization measurements of the stability in frequency as well as intensity of the lasers.

Q 25.29 Tue 16:30 S Atrium Informatik

Towards a lithium quantum gas microscope for small quantum systems — •Michael Hagemann, Andreas Kerkmann, Mathis Fischer, Benno Rem, Klaus Sengstock, and Christof Weitenberg — Institute for Laser Physics, University of Hamburg, Luruper Chaussee 149, 22761 Hamburg, Germany

We are setting up a new quantum gas microscope for the preparation and detection of degenerate samples of ^{6}Li / ^{7}Li atoms to study strong correlations in small quantum systems. The setup consists of a compact 2D- / 3D-MOT chamber without further transport optimized for short cycle times.

We report on the realization of a molecular BEC of fermionic ^{6}Li atoms using an all-optical cooling procedure including lambda enhanced gray molasses and evaporation in a crossed optical dipole trap. We show that we can drive a well-controlled intensity ramp for the evaporation with an extinction ratio in laser power of more than three orders of magnitude by using a wave plate in a motorized rotating mount alone, thereby avoiding the thermal effects in acousto-optical modulators.

In addition, we will show the progress of the installation of the high-resolution microscope objective and the loading of the BEC into a 2D triangular lattice and a 1D accordion lattice.

Q 25.30 Tue 16:30 S Atrium Informatik

Scaling it up: From few to many — •Keerthan Subramanian, Luca Bayha, Marvin Holten, Antonia Klein, Puneet Murthy, Philipp Preiss, Gerhard Zürn, and Selim Jochim — Physikalisches Institut, Universität Heidelberg, Germany

In a novel, bottom-up approach we present first few results toward studying many-body states at low entropy. Starting with, for example, two spin states and two atoms in a microtrap, we deform the potential adiabatically to a double well using a Spatial Light Modulator(SLM), which can also be used to create tailored optical potentials. To study the Hubbard model for instance, we plan to create double wells in ground states and adiabatically merge them creating a many-body state at low entropy reminiscent of quantum Lego blocks. To this end we have already demonstrated deterministic preparation of few-fermion systems in controlled quantum states in a double well. This preparation capability is complemented with single particle position and momentum imaging with spin readout in free-space using an EMCCD. Since an atom can be imaged by detecting as few as ~25 photons, elaborate cooling schemes and pinning during imaging are not warranted thereby distinguishing it from existing quantum gas microscopes. With this mix of deterministic preparation, tailored optical potentials, tunable interactions and single particle imaging we present first glimpses of finite size systems, like plaquettes, that we study before embarking on more complicated many-body systems.

Q 25.31 Tue 16:30 S Atrium Informatik

Engineering exotic optical potentials for ultracold fermions — •Jeffrey Mohan, Samuel Häusler, Laura Corman, Philipp Fabritius, Martin Lebrat, Dominik Husmann, and Tilman Esslinger — Institute for Quantum Electronics, ETH Zurich

We describe our experiment for studying transport phenomena in ultracold fermionic lithium through optically-defined mesoscopic structures. Using a digital micromirror device (DMD) as a spatial light modulator in conjunction with a high-resolution microscope, we can engineer additional potential landscapes that can go beyond what is feasible in corresponding solid-state systems. We have successfully applied this technique, for example, to imprint a lattice on the QPC whose gap was observed in the system's transport characteristics [1], to implement a cold atom scanning gate microscope with a tightly-focused repulsive spot [2], and to insert a spin filter with a beam tuned in frequency between the two hyperfine states. With a recent improvement to our method of generating DMD patterns, we have improved the power efficiency of the potential projection by an order of magnitude and have significantly enhanced the fidelity of the resulting fields. With this new capability, we plan to investigate more complex structures such as time-varying fields, spin-dependent lattices, and spatially-engineered dissipation.

[1] Lebrat *et al.*, Phys. Rev. X **8**, 011053, 2018
[2] Häusler *et al.*, Phys. Rev. Lett. **119**, 030403, 2017

Q 25.32 Tue 16:30 S Atrium Informatik

Beyond particle transport through a quantum point contact using ultracold atoms — •Samuel Häusler, Dominik Husmann, Martin Lebrat, Philipp Fabritius, Jeffery Mohan, Jean-Philippe Brantut, Laura Corman, and Tilman Esslinger — ETH Zurich, 8093 Zürich, Switzerland

Transport measurements through a quantum system probes its excitations which, in the case of strongly correlated matter, are challenging to characterise. Particle transport, an essential observable in solid state physics, is measured in our cold atom system consisting of two reservoirs of fermionic lithium atoms connected by a quantum point contact. Here, we go beyond pure particle transport by combining it with either heat or spin transport.

First, we study the coupling between particle and heat currents at unitarity close to the superfluid transition. After heating one reservoir, we observe an extreme initial particle current from cold to hot that brings the system to a non-equilibrium steady state where currents vanish. The steady state reveals a finite particle and suppressed thermal conductance, thus violating the Wiedemann-Franz law.

Second, we recently implemented a spin filter by shining a near-resonant tweezer inside the channel. It blocks particles of one spin species while allowing the other to pass, thereby realising a strong, local effective Zeeman field on the order of the Fermi energy. We are thus able to create fully spin-polarized currents in the presence of conductance quantization. Furthermore, we increase dissipation induced by the tweezer and tune interactions.

Q 25.33 Tue 16:30 S Atrium Informatik

Topological phases of mixed states and their detection — •Lukas Wawer and Michael Fleischhauer — TU Kaiserslautern

Topological states of matter have fascinated physicists since a long time due to the exotic properties of elementary excitations and the topological protection of edge states and currents. Motivated by topological charge pumps, we will introduce a classification for topological phases of matter applicable to finite-temperature states as well as stationary states of driven, dissipative systems based on a generalization of the many-body polarization. For non-interacting fermions it defines an ensemble topological phase (ETP), which in the thermodynamic limit is the Zak or Berry phase of a ficticious Hamiltonian given by the covariance matrix of single-particle correlations [1]. As examples, we discuss a Thouless pump in steady state of the one dimensional finite-temperature Rice-Mele model and a scheme that maps the covariance matrix to the hamiltonian of an auxiliary system of free fermions at $T = 0$. This allows to directly observe the ficticious Hamiltonian and the same scheme can be used to transfer topological properties from an interacting to a non-interacting system. [1]C.E. Bardyn, L. Wawer, A. Altland, M. Fleischhauer, S.Diehl, Phys. Rev. X (2018)

Q 25.34 Tue 16:30 S Atrium Informatik

Engineering and measuring density-dependent Peierls phases as a fundamental coupling mechanism of gauge and matter fields — •Kilian Sandholzer, Frederik Görg, Joaquín Minguzzi, Konrad Viebahn, Rémi Desbuquois, Michael Messer, and Tilman Esslinger — ETH Zürich, Switzerland

The implementation of artificial gauge fields for cold atoms in optical lattices established these systems as a powerful tool to study the effects of electromagnetic fields and spin-orbit coupling. So far, the gauge potentials were classical external fields without any back-action from the atoms and could, therefore, not reproduce a full lattice gauge theory. We present and implement a scheme that realizes the coupling mechanism via a non-trivial Peierls phase that depends on the site occupation of fermions in a Hubbard dimer. We use a two color driving scheme that explicitly breaks time-reversal symmetry and determine experimentally amplitude and phase of the tunneling process. In addition, we demonstrate the phase winding and gap closing induced by a Dirac point in the modulation parameter space.

Q 25.35 Tue 16:30 S Atrium Informatik

Towards Non-Destructive transport measurements of inter-

acting Fermions — •Kevin Roux, Victor Helson, Barbara Cilenti, Hideki Konishi, and Jean-Philippe Brantut — Laboratory for Quantum Gases, EPFL, Switzerland

In recent years, it has become possible to investigate transport phenomena using ultracold atoms in a two-terminal configuration where two reservoirs are connected through a mesoscopic channel. The measurements, however, rely on comparing different samples because of the destructive nature of probing methods, which makes the measurements sensitive to even very weak fluctuation in the atomic sample preparation. In order to achieve more precise measurements, we will implement non-destructive measurements of the atomic current featuring the cavity QED technique. We are currently developing a new apparatus where a degenerate Fermi gas of lithium-6 will be coupled to a high-finesse optical cavity. In the poster, we will discuss the non-destructive probing scheme using the high-finesse cavity and present the recent progress on the experimental apparatus.

Q 25.36 Tue 16:30 S Atrium Informatik

Benchmarking non-equilibrium DMFT and ultracold fermions in optical lattices to study the driven Fermi-Hubbard model — •Joaquín Minguzzi[1], Kilian Sandholzer[1], Yuta Murakami[2], Frederik Görg[1], Michael Messer[1], Konrad Viebahn[1], Rémi Desbuquois[1], Martin Eckstein[3], Philipp Werner[2], and Tilman Esslinger[1] — [1]ETH Zürich, Switzerland — [2]Universitz of Fribourg, Switzerland — [3]University of Erlangen-Nürnberg, Germany

Numerical simulations and quantum simulations based on ultracold fermions in optical lattices are by now benchmarked approaches to study the Fermi-Hubbard model, which describes correlated electrons in solids. A wide variety of novel quantum effects become accessible when a quantum system is periodically driven, which is known as Floquet engineering. Here, non-equilibrium dynamical mean field theory and ultracold fermions in optical lattices are used to study strongly interacting particles on a modulated lattice. We perform an experiment-theory comparison by studying the double occupancy dynamics in a driven Fermi-Hubbard model on a three-dimensional lattice. When the driving frequency is close to the interaction energy, double occupancies are created via resonant tunneling processes. These novel hopping mechanisms are studied in the effective static description, and the influence of the filling factor and driving amplitude is investigated. Good agreement between our methods prove the validity of the Floquet Hamiltonian description. A future direction to be explored is magnetic correlations in a Floquet engineered fully tunable t-J Hamiltonian.