A 29: Ultra-cold atoms, ions and BEC III (with Q)

Time: Wednesday 14:00–16:00 Location: UDL HS3038

Invited Talk A 29.1 Wed 14:00 UDL HS3038

Single charged impurities inside a Bose-Einstein condensate — •Sebastian Hofferberth[1], Jonathan Balewski[1], Alexander Krupp[1], Anita Gaj[1], David Peter[2], Hanspeter Büchler[2], Robert Löw[1], and Tilman Pfau[1] — [1]5. Phys. Institut, Universität Stuttgart, Germany — [2]Institut für Theoretische Physik III, Universität Stuttgart, Germany

We investigate the interaction of single charged impurtities with a Bose-Einstein condensate (BEC). We produce these impurities by exciting exactly one atom from the BEC to a Rydberg state. Since the ionic core and the Rydberg electron have vastly different mass and interaction range with the surrounding ground state atoms, their effect on the BEC can be observed separately. For low-L Rydberg states, the electron wavefunction is fully immersed in the BEC, and we observe electron-phonon coupling. We show that a single electron excites collective modes of the whole condensate. We also discuss the feasibility of studying the interaction of the ionic core with the BEC, which becomes possible if the electron is excited to a high-L states such that it is moved completely outside of the BEC. In this situation one could study ion-ground state Feshbach resonances at very low temperatures or trap the ion inside the BEC without any external electric fields.

A 29.2 Wed 14:30 UDL HS3038

Field-theoretical Study of the Bose Polaron - Challenges for Quantum Simulation with ultracold Atoms — •Richard Schmidt[1,2] and Steffen Patrick Rath[3] — [1]ITAMP, Harvard-Smithsonian Center for Astrophysics, Cambridge, Massachusetts 02138, USA — [2]Department of Physics, Harvard University, Cambridge, Massachusetts 02138, USA — [3]Technische Universitaet Muenchen, James-Franck-Straße, 85748 Garching, Germany

We study the properties of the Bose polaron, an impurity strongly interacting with a Bose-Einstein condensate, using a field-theoretic approach and make predictions for the spectral function and various quasiparticle properties that can be tested in experiment. We find that most of the spectral weight is contained in a coherent attractive and a metastable repulsive polaron branch. We show that the qualitative behavior of the Bose polaron is well described by a T-matrix approximation. We discuss the implications of our results for the attempted quantum simulation of the Froehlich Hamiltonian using ultra cold atoms.

A 29.3 Wed 14:45 UDL HS3038

Bose-Einstein condensation of ultra-cold atoms in a frustrated, triangular optical lattice I. — •Ludwig Mathey[1], Robert Höppner[1], Peter Janzen[1], Julian Struck[1], Malte Weinberg[1], Christoph Ölschläger[1], Patrick Windpassinger[1], Juliette Simonet[1], Klaus Sengstock[1], Philipp Hauke[2], Andre Eckardt[3], and Maciej Lewenstein[4] — [1]Institut für Laserphysik and Zentrum für Optische Quantentechnologien, Universität Hamburg, Hamburg, Germany — [2]IQOQI, Innsbruck, Austria — [3]MPIKS, Dresden, Germany — [4]ICFO and ICREA, Barcelona, Spain

We present a study of Bose-Einstein condensation of ultracold atoms in a triangular optical lattice. As demonstrated in Ref. [1], the tunneling energy between neighboring sites in an optical lattice can be controlled via lattice shaking to be negative or complex-valued. For negative, real-valued tunneling, the system condenses at one of two non-zero quasimomenta, corresponding to classical frustration. Tuning the tunneling energy to complex values corresponds to an artificial gauge field. We demonstrate that the nature of the condensation transition is modified due an additional chiral symmetry that is broken. Furthermore, the artificial gauge field acts as the conjugate external field to the chiral order parameter, which allows to map out magnetization curves of the chirality as a function of the article gauge field. In this talk we give analytical results on the nature of the phase transition, based on an expansion of the free energy in the interaction strength and on a renormalization group approach.

[1] J.Struck, et al., Nature Physics 9, 738 (2013)

A 29.4 Wed 15:00 UDL HS3038

Bose-Einstein condensation of ultra-cold atoms in a frustrated, triangular optical lattice II. — Robert Höppner[1], Julian Struck[1], Malte Weinberg[1], Christoph Ölschläger[1], Patrick Windpassinger[1,3], Juliette Simonet[1], Klaus Sengstock[1], Ludwig Mathey[1], •Philipp Hauke[5], André Eckardt[4], and Maciej Lewenstein[2] — [1]ILP/ZOQ (Hamburg) — [2]ICFO/ICREA — [3]Uni Mainz — [4]MPIPKS — [5]Uni Innsbruck

We study the condensation in frustrated, triangular optical lattices, with emphasis on numerical simulations. We implement the system using a semiclassical version of the Bose-Hubbard model and generate samples of the grand-canonical ensemble using Metropolis Monte-Carlo from which we then calculate the observables. As discussed in Ref. [1], periodic driving of the optical lattice potential generates an effective tunneling energy that becomes complex, thereby creating an artificial gauge-field that acts as a control field of the chiral order that emerges in this system. In analogy to the experimental study, we numerically determine the magnetization curves of the chiral order parameter as function of the artificial gauge field. We demonstrate that the experimentally realized ensemble is not in equilibrium, showing hysteric-like behavior. Beyond the equilibrium system, we therefore also comment on the quench dynamics from the positive tunneling (ferromagnet-like phase) to the negative tunneling, fully frustrated phase.

[1] "Engineering Ising-XY spin-models in a triangular lattice using tunable artificial gauge fields." Nature Physics (2013)

A 29.5 Wed 15:15 UDL HS3038

A novel experiment for coupling a Bose-Einstein condensate with two crossed cavity modes — •Julian Leonard, Moonjoo Lee, Andrea Morales, Thomas Karg, Tilman Esslinger, and Tobias Donner — ETH Zürich, Institute for Quantum Electronics, Zürich, Switzerland

Over the last decade, combining cavity quantum electrodynamics and quantum gases allowed to explore the coupling of quantized light fields to coherent matter waves, leading e.g. to new optomechanical phenomena and the realization of quantum phase transitions. Triggered by the interest to study setups with more complex cavity geometries, we built a novel, highly flexible experimental system for coupling a Bose-Einstein condensate (BEC) with optical cavities, which allows to switch the cavity setups by means of an interchangeable science platform. The BEC is generated from a cloud of laser-cooled 87-Rb atoms which is first loaded into a hybrid trap, formed by a combined magnetic and optical potential, and then optically transported into the cavity setup, where it is cooled down to quantum degeneracy.

At first we aim to explore the coupling of a BEC with two crossed cavity modes. We report on our progress on the implementation of a science setup involving two cavities intersecting under an angle of 60°. The mirrors have been fabricated in order to spatially approach them, thus obtaining maximum single atom coupling rates of several MHz. This setup will allow us to study the coherent interaction of a BEC and the two cavity modes both in internal lambda-level transitions and in spatial self-organization processes in dynamical hexagonal lattices.

A 29.6 Wed 15:30 UDL HS3038

Microscopic description of Bose-Einstein condensates in complex potentials — •Dennis Dast, Daniel Haag, Holger Cartarius, and Günter Wunner — 1. Institut für Theoretische Physik, Universität Stuttgart

Bose-Einstein condensates with balanced gain and loss are described in mean-field approximation by a non-Hermitian but $\mathcal{PT}$-symmetric Gross-Pitaevskii equation. To gain a deeper understanding of the non-Hermitian Hamiltonian a microscopic treatment of the incoupling and outcoupling of particles is necessary. We do this by modelling the open system as a subsystem of a closed system. The complete system including the environment is described, on the one hand, by a many-particle Bose-Hubbard Hamiltonian. On the other hand, a Lindblad master equation is used to describe gain and loss in the open quantum system. The behaviour of the Bose-Hubbard Hamiltonian and the Lindblad master equation are compared with the non-Hermitian mean-field description.

A 29.7 Wed 15:45 UDL HS3038

On the Validity of the Truncated Wigner Method for Bosonic Many Body Transport — •Thomas Engl[1], Julien Dujardin[2], Juan Diego Urbina[1], Klaus Richter[1], and Peter Schlagheck[2] — [1]Institut für Theoretische Physik, Universität Regensburg, D-93040

Regensburg, Germany — [2]Département de Physique, Université de Liège, 4000 Liège, Belgium

The Truncated Wigner Method is one of the most frequently used approaches to investigate bosonic many body systems. It is based on the evolution of the Wigner function of the initial state, which is sampled by Gross-Pitaevskii trajectories that are generated by the corresponding mean field Hamiltonian. However, since this is the classical evolution with respect to the quantum Hamiltonian, this method cannot account for interference phenomenons on the many-body quantum level. This concerns in particular coherent backscattering in Fock Space, which arises due to constructive interference of time reversed Gross-Pitaevskii trajectories [1]. Here, we prove the validity of the Truncated Wigner approximation, *i.e.* the cancellation of quantum many-body interference, for bosonic many-body transport in the semiclassical limit, by extending the semiclassical approach developed in our previous work [1].

[1] T. Engl, J. Dujardin, A. Argüelles, P. Schlagheck, K. Richter and J. D. Urbina, arXiv:1306.3169