Q 38: Quantum Gases: Bosons III / Lattices I

Time: Wednesday 16:30–19:00 Location: E 001

Q 38.1 We 16:30 E 001

Dipolar Bose-Einstein condensates: stability properties and physics in deep optical lattices. — •Kazimierz Łakomy[1], Rejish Nath[1,2], and Luis Santos[1] — [1]Institut für Theoretische Physik , Leibniz Universität, Hannover, Appelstrasse 2, D-30167, Hannover, Germany — [2]Max Planck Institute for the Physics of Complex Systems, Nöthnitzer Strasse 38, D-01187 Dresden, Germany

Due to their partially attractive character, dipole-dipole interactions may drive instability in dipolar gases. In this presentation we analyze in detail the instability of pancake-like condensates both against phonon- and the roton-instability as a function of the dipole strength and the strength of short-range interactions. After briefly reviewing the different types of instabilities in dipolar condensates, we show that the boundary between stability and roton instability presents a reentrant shape, which allows for scenarios where the system is only stable for a window of dipole strengths, i.e. the system is photon- or roton-unstable for small and large dipole-strengths. We determine as well the universal critical short-range interaction below which the gas is always unstable. In the last part of the talk we shall discuss recent results on the properties of solitons in dipolar condensates in deep optical lattices.

Q 38.2 We 16:45 E 001

Interaction of a BEC with a surface: towards a many-body cavity QED — •Jürgen Schiefele and Carsten Henkel — Universität Potsdam, Institut für Physik und Astronomie

We consider the collective Casimir-Polder interaction between a trapped gas of condensed Bosons and a plane surface through the coupling of the condensate atoms with the electromagnetic field. Technically, we aim at a systematic perturbation theory describing the electromagnetic self-energy of a trapped Bose gas near a surface. In the leading order, the interaction energy is—as expected—proportional to the number of atoms in the condensate mode, but atom-atom interactions lead to corrections compared to the single-atom theory. The interaction energy in the next order is proportional to the number of pairs in the condensate mode.

Q 38.3 We 17:00 E 001

Quantum phases of polar bosons in ladder-like lattices — •Xiaolong Deng and Luis Santos — ITP, Leibniz Universität Hannover, Hannover, Germany

In this work we numerically investigate by DMRG polar bosons, e.g. polar bosonic molecules, loaded in a two-leg ladder. We are particularly interested in the role played by the inter-site dipole-dipole interaction in the ground-state phases of the system. We evaluate ground-state correlation functions, characterize various quantum phases for different interaction regimes, and identify the phase diagram for different fillings. We also predict some novel quantum phases which appear when incorporating the true long-range and anisotropic character of the dipole-dipole interaction.

Q 38.4 We 17:15 E 001

Measuring atomic correlations via photon counting — •Stefan Rist[1,2] and Giovanna Morigi[1] — [1]Theoretische Physik, Universität des Saarlandes, D-66041 Saarbrücken, Germany — [2]Departament de Fisica, Universitat Autonoma de Barcelona, E-08193 Bellaterra, Spain

A scheme is presented, which allows one for measuring the quantum state of an ultracold atomic gas by means of the first-order coherence of light, which interacts dispersively with the gas. The scheme is based on an interferometric-like setup, and allows one for determining, amongst others, the single-particle correlation function, as well as correlations between atomic field and density. The results are evaluated for ultracold atoms in one- and two-dimensional optical lattices, across the superfluid / Mott-insulator transition.

Q 38.5 We 17:30 E 001

Single site addressability in optical lattices — •Christof Weitenberg[1], Manuel Endres[1], Jacob Sherson[1], Marc Cheneau[1], Rosa Glöckner[1], Ralf Labouvie[1], Immanuel Bloch[1,2], and Stefan Kuhr[1] — [1]Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Str. 1, 85748 Garching — [2]Ludwig-Maximilians-Universität, Fakultät für Physik, Schellingstr. 4, 80799 München

Single site resolution in short-wavelength optical lattices, which have a significant tunnel coupling, is a challenging task. We prepare a BEC of rubidium atoms in a 3D lattice of 532 nm spacing. Using the 5S1/2 to 6P3/2 transition at 420nm, our imaging system (NA=0.7) will yield a resolution of 380nm and there-fore allow single site resolved detection and manipulation.

So far we have taken in trap fluorescence images with a resolution of 700 nm using the 5S1/2 to 5P3/2 transition at 780nm and demonstrated the micro-manipulation of a few atoms with a tightly focused dipole trap. To extract one or a few slices and remove the atoms that are out of the depth of focus we use microwave transitions in a magnetic field gradient.

The single site resolution will open up a new class of experiments in quantum simulation of strongly correlated systems - like the in-situ observation of the Mott insulator or the investigation of non-equilibrium phenomena - and in quantum information processing - like local spin manipulation or quantum gates with Rydberg atoms.

Q 38.6 We 17:45 E 001

Quantum Gas Microscope - A Next Generation Quantum Simulator — •Markus Greiner[1], Waseem Bakr[1], Jonathon Gillen[1], Amy Peng[1], and Simon Foelling[2] — [1]Harvard-MIT Center for Ultracold Atoms and Department of Physics, Harvard University, Cambridge, MA, USA — [2]Ludwig-Maximilians-Universität, Munich, Germany

Ultracold atoms give the unique opportunity to experimentally realize and study increasingly complex many-body quantum systems. One approach is to employ large samples of ultracold atoms and, for example, carry out quantum simulations of condensed-matter models. The opposite approach is to assemble quantum information systems with full control over all degrees of freedom, atom by atom, ion by ion. I will present work in which we have created a quantum gas microscope that bridges between these two worlds. Thousands of individual atoms are detected with near-unity fidelity on individual sites of a Hubbard regime optical lattice. In addition, the single site addressability can be used for creating arbitrary potential landscapes and for local atom manipulation. This novel approach opens many new possibilities for quantum simulations and quantum information applications.

Q 38.7 We 18:00 E 001

Confinement-induced resonances in 1D quantum systems — •Elmar Haller, Manfred J. Mark, Johann G. Danzl, Russell Hart, Lukas Reichsöllner, Andreas Klinger, Oliver Krieglsteiner, and Hanns-Christoph Nägerl — Institut für Experimentalphysik und Zentrum für Quantenphysik, Universität Innsbruck, Technikerstraße 25, A-6020 Innsbruck, Austria

Strong external potentials can be employed to confine atoms to one-dimensional (1D) and two-dimensional (2D) spatial geometry. For a 1D system with strong repulsive interaction, a dramatic change of the atomic scattering properties is predicted as the s-wave scattering length approaches the transversal confinement length [1]. We report on the observation of such a confinement-induced resonance (CIR) in a degenerate gas of Cs atoms in a 2D optical lattice. The versatility of a confinement-controlled interaction strength is demonstrated by creating a double resonance with a transversally asymmetric wave guide. We observe a splitting of the CIR and the occurrence of additional scattering resonances. One possible application of a CIR is the creation of a “super Tonks Girardeau gas”, which is an excited, strongly-correlated gas phase with strong attractive interaction [2,3].

[1] M. Olshanii, Phys. Rev. Lett. **81**, 938-941 (1998).
[2] E. Haller, et. al., Science **325**, 1224 (2009).
[3] E. Astrakharchik, et. al., Phys. Rev. Lett. **95**, 190407 (2005).

Q 38.8 We 18:15 E 001

Paired and Usual Superfluidity in Spin-1 Optical Lattices — •Leonardo Mazza[1], Matteo Rizzi[1], Maciej Lewenstein[2], and J.Ignacio Cirac[1] — [1]Max-Planck Institut für Quantenoptik, Garching, Deutschland — [2]ICREA and ICFO, Barcelona, Spain

We discuss the possibility of simulating three-body repulsive contact interactions using experimentally feasible ultracold atoms setups. In particular, we consider a spin-1 (F=1) atomic Mott insulator (MI) with one atom per site, whose three local degrees of freedom are mapped into local bosonic occupation numbers less than two. This simulates a system with infinite three-body repulsion and null two-body interaction. Suitable laser assisted couplings via an auxiliary F=2 ancilla tailor the ratio between single-particle and pair-correlated hopping.

This suggests to explore an enriched phase diagram where also a pair-superfluid (PSF) is present. First of all, we investigate the transition between the usual superfluid phase (SF) and the paired one as a function of particle density and ratio of the two hopping parameters. Numerics is performed in 1D with DMRG and algebraic decay of correlations is exploited to discriminate the phases.

Finally, we move on to the theoretical Hubbard model with the insertion of the pair-correlated hopping term. Besides the usual MI for dominating two-body repulsion, and SF phase for prevailing single-particle hopping parameter, a collapsed phase emerges when the paired hopping is leading. This strongly restricts the PSF region of the phase diagram, and motivates resorting to the previous experimental proposal in order to observe such an exotic phase.

Q 38.9 We 18:30 E 001

Two-mode Bose gas: Beyond classical squeezing — •Cédric Bodet and Thomas Gasenzer — Institut für Theoretische Physik, Universität Heidelberg, Philosophenweg 16, 69120 Heidelberg

The dynamical evolution of squeezing correlations in an ultracold Bose-Einstein distributed across two modes is investigated theoretically in the framework of the Bose-Hubbard model. We study the development of non-classical correlations and relative number squeezing in regimes where the system is strongly interacting. Comparing the full quantum evolution with classical statistical simulations allows to identify quantum aspects of the squeezing formation. In the quantum regime, the measurement of squeezing allows to distinguish even and odd total particle numbers.

Q 38.10 We 18:45 E 001

Enhancement and suppression of the Landau-Zener tunneling in the presence of time-dependent disorder — •Ghazal Tayebirad[1,2] and Sandro Wimberger[1,2] — [1]Institüt für Theoretische Physik, Universität Heidelberg, Philosophenweg 19, D-69120 — [2]Heidelberg Graduate School of Fundamental Physics, Albert-Ueberle-Str. 3-5, D-69120

We investigate the coherent control of the transport and of the decay of Bose-Einstein condensates from the ground band in a lattice structure with time-dependent disorder. To this respect, we study the time evolution of ultra-cold atoms loaded into a quasi-1D geometry supporting a stochastic potential and subjected to an additional static force. Our disordered lattice can be created by superimposing two standing waves with incommensurable wavelengths which have a time-dependent random phase shift with respect to each other. We demonstrate that stochastic noise [1] in the system can be used to engineer the transport of ultra-cold atoms without changing system intrinsic parameters. Our results show how an appropriately chosen random phase either enhances, suppresses, or hardly affects the Landau-Zener tunneling out of the ground band of the lattice.

[1] R. Mannella, A gentle introduction to the integration of stochastic differential equations, Lecture Notes in Physics, 557 (Springer, Heidelberg, 2000)