Q 36: Ultra-cold atoms, ions and BEC IV (with A)

Time: Wednesday 11:00–12:30 Location: F 428

Q 36.1 Wed 11:00 F 428

Mott-insulator state of ultracold atoms in optical lattices: comparison of exact numerical results with controlled approximations — •Konstantin Krutitsky, Friedemann Queisser, Patrick Navez, and Ralf Schützhold — Fakultät für Physik, Universität Duisburg-Essen, Duisburg, Germany

A wide class of phenomena for ultra-cold atoms in deep optical lattices is well described by the Bose-Hubbard model. Using exact numerical and approximate analytical methods, we have studied the ground-state energy, probabilities of the occupation numbers of the individual lattice sites, two-point correlation functions, and the excitation spectrum, in the Mott-insulator regime. Exact results are obtained for one-dimensional lattices up to 14 sites and for two-dimensional lattices of 3x3 sites. They are compared with the fourth order expansion in the ratio of the tunneling rate J and the interaction constant U valid in an arbitrary dimensions and the inverse coordination number 1/Z valid for arbitrary interaction strengths. The zeroth order in 1/Z is equivalent to the Gutzwiller mean field [3]. In one dimension, numerical data nearly coincide with perturbation theory in J/U whereas the first-order results in 1/Z deviate a bit for increasing J. In two dimensions, the 1/Z expansion is already superior to the J/U expansion, and should become even better in three and higher dimensions.

[1] J.K.Freericks and H.Monien, Phys.Rev.B 53, 2691 (1996).

[2] F.Queisser, K.V.Krutitsky, P.Navez, R.Schützhold, arXiv:1203.2164.

[3] S.Sachdev, Quantum phase transitions, Cambridge University Press, 2001.

Q 36.2 Wed 11:15 F 428

Density waves in dipolar Bose-Einstein condensates — •Alexandru Nicolin — Horia Hulubei National Institute for Physics and Nuclear Engineering, Magurele, Romania

Density waves in cigar-shaped dipolar Bose-Einstein condensates are analysed by variational means and we show analytically how the dipole-dipole interaction between the atoms generates a roton-maxon excitation spectrum. A simple model is used to derive the effective equations which describe the emergence of the density waves.

Q 36.3 Wed 11:30 F 428

Mode Entanglement in Systems of Massive, Indistinguishable Bosons — •Felix Binder[1], Libby Heaney[2], Dieter Jaksch[1,2], and Vlatko Vedral[1,2,3] — [1]Clarendon Laboratory, Department of Physics, University of Oxford, Parks Road, Oxford OX1 3PU, UK — [2]Center for Quantum Technologies, National University of Singapore, 3 Science Drive2, 117543, Singapore — [3]Department of Physics, National University of Singapore, 2 Science Drive 3, 117542, Singapore

The standard notion of entanglement breaks down in systems of indistinguishable particles due to a loss of the tensor product structure of Hilbert space. Nevertheless, second quantisation allows us to describe entanglement between spatial modes which arises naturally in Bose-Einstein condensates or optical lattices.

Under particle-number superselection rules the only basis for the description of these systems is the mode-occupation basis, where it is possible to study and quantise correlations, for example via their relation to the visibility of interference fringes and the single-particle reduced density matrix.

In order to genuinely detect or harness entanglement, however, it is ultimately necessary to locally overcome the particle-number superselection rules by providing a suitable reference frame. It will be shown how this is possible using a BEC reservoir as the reference frame and a proposed implementation scheme for an optical lattice system will be described. This scheme could be used to experimentally test entanglement between modes of massive, indistinguishable bosons for the first time.

Q 36.4 Wed 11:45 F 428

Dynamics of Bose-Einstein condensates in $\mathcal{PT}$-symmetric double-well potentials — •Daniel Haag, Dennis Dast, Holger Cartarius, and Günter Wunner — 1. Institut für Theoretische Physik, Universität Stuttgart

The study of non-Hermitian Hamiltonians has attracted large attention in recent years. A special class of such systems are described by non-Hermitian but $\mathcal{PT}$-symmetric Hamiltonians that can have entirely real spectra. In general, non-Hermitian systems do not conserve the norm of a wave packet, which has a severe effect on the dynamics of nonlinear systems such as Bose-Einstein condensates described by the Gross-Pitaevskii equation. We investigate the stability of the eigenstates and solve the time-dependent GPE for a $\mathcal{PT}$-symmetric double well, where in one well particles are removed while particles are coherently injected into the other.

Q 36.5 Wed 12:00 F 428

Superfluidity with disorder in a quantum gas thin film — •Sebastian Krinner, David Stadler, Jakob Meineke, Jean-Philippe Brantut, and Tilman Esslinger — Institute for Quantum Electronics, ETH Zürich, Switzerland

We investigate the properties of a strongly interacting, superfluid gas of $^6Li_2$ Feshbach molecules forming a thin film confined in a quasi two-dimensional channel with a tunable random potential, creating a microscopic disorder. We measure the atomic current and extract the resistance of the film in a two-terminal configuration, and identify a superfluid state at low disorder strength, which evolves into a normal, poorly conducting state for strong disorder. The transition takes place when the chemical potential reaches the percolation threshold of the disorder.

The evolution of the conduction properties contrasts with the smooth behavior of the density and compressibility across the transition, measured in-situ at equilibrium. These features suggest the emergence of a glass-like phase at strong disorder.

Q 36.6 Wed 12:15 F 428

Three-body recombination in a quasi-two-dimensional quantum gas — •Bo Huang[1], Alessandro Zenesini[1], Martin Berninger[1], Hanns-Christoph Nägerl[1], Francesca Ferlaino[1], and Rudolf Grimm[1,2] — [1]Institut für Experimentalphysik und Zentrum für Quantenphysik, Universität Innsbruck, 6020 Innsbruck, Austria — [2]Institut für Quantenoptik und Quanteninformation (IQOQI), Österreichische Akademie der Wissenschaften, 6020 Innsbruck, Austria

Collisional properties of interacting particles can dramatically change when the dimensionality of the system is reduced. One intriguing example is the disappearance of the weakly bound trimers known as Efimov states in two dimensions. Many open questions remain about the details of the crossover from three to two dimensions and how the Efimov-related three-body recombination losses are affected. We use ultracold cesium atoms trapped tightly in a harmonic potential along one spatial direction to realize a quasi-two-dimensional system with tunable confinement and tunable interactions. In our latest results, we succeed to trace a smooth transition of the three-body recombination rate from a three-dimensional to a nearly two-dimensional system, in good agreement with recent theoretical models.