Q 17: Bose-Einstein Condensation (joint session A/Q)

Time: Monday 14:00–16:15 Location: K 2.016

Q 17.1 Mon 14:00 K 2.016

Nonequilibrium Quantum Phase Transition in a Hybrid Atom-Optomechanical System — •Niklas Mann[1], M. Reza Bakhtiari[1], Axel Pelster[2], and Michael Thorwart[1] — [1]I. Institut für Theoretische Physik, Universität Hamburg, Jungiusstraße 9, 20355 Hamburg, Germany — [2]Physics Department and Research Center OPTIMAS, Technical University of Kaiserslautern, Erwin-Schrödinger Straße 46, 67663 Kaiserslautern, Germany

We consider a hybrid quantum many-body system formed by both a vibrational mode of a nanomembrane, which interacts optomechanically with light in a cavity, and an ultracold atom gas in the optical lattice of the out-coupled light. After integrating over the light field, an effective Hamiltonian reveals a competition between the localizing potential force and the membrane displacement force. For increasing atom-membrane interaction we find a nonequilibrium quantum phase transition from a localized non-motional phase of the atom cloud to a phase of collective motion. Near the quantum critical point, the energy of the lowest collective excitation vanishes, while the order parameter of the condensate becomes non-zero in the symmetry-broken state. The effect occurs when the atoms and the membrane are non-resonantly coupled.

Q 17.2 Mon 14:15 K 2.016

Second sound across the BEC-BCS crossover — •Vijay Pal Singh[1,2,3], Daniel Kai Hoffmann[4], Thomas Paintner[4], Wolfgang Limmer[4], Johannes Hecker Denschlag[4], and Ludwig Mathey[1,2,3] — [1]Zentrum für Optische Quantentechnologien, Universität Hamburg, 22761 Hamburg, Germany — [2]Institut für Laserphysik, Universität Hamburg, 22761 Hamburg, Germany — [3]The Hamburg Centre for Ultrafast Imaging, Luruper Chaussee 149, Hamburg 22761, Germany — [4]Institut für Quantenmaterie, Universität Ulm, 89081 Ulm, Germany

We report on the first and second sound measurements across the BEC-BCS crossover and their theoretical analysis. The measurements are performed in a cigar-shaped three-dimensional cloud of ^{6}Li atoms and molecules. First sound is excited by an external potential that couples to the density, while second sound is excited by a potential modulation resulting mainly in local heating. The velocity of first and second sound is extracted from the propagation of the excited density wave. We find that the second sound velocity is reduced with decreasing cloud density and vanishes at the superfluid-thermal boundary, whereas the first sound velocity is only weakly affected by the cloud density. We compare the experiments on the BEC side of the crossover to numerical simulations and find good agreement.

Q 17.3 Mon 14:30 K 2.016

Zeeman Effect in Spinor Condensates: Tuning the Mott-Superfluid transition and the Nematic Order — •Laurent de Forges de Parny[1] and Valy Rousseau[2] — [1]Physikalisches Institut, Albert-Ludwigs-Universität Freiburg, Hermann-Herder-Straße 3, D-79104, Freiburg, Germany — [2]Physics Department, Loyola University New Orleans, 6363 Saint Charles Ave., LA 70118, USA

Spinor condensates, namely Bose-Einstein condensates with internal degree of freedom, allow for the investigation of quantum magnetism [1]. When loaded into an optical lattice, these systems can be described by an extended Bose-Hubbard model with spin-spin interactions [2]. Using quantum Monte Carlo simulations, we study the Zeeman effect in a system of antiferromagnetic spin-1 bosons trapped in a square lattice at zero temperature. The Zeeman effect strongly affects the Mott-superfluid transition and the magnetic properties, e.g. the singlet state and the nematic order.

[1] D. M. Stamper-Kurn and M. Ueda, Rev. Mod. Phys. 85, 1191 (2013);

[2] A. Imambekov, M. Lukin, and E. Demler, Phys. Rev. A 68, 063602 (2003).

Q 17.4 Mon 14:45 K 2.016

Spatial entanglement and Einstein-Podolsky-Rosen steering in a Bose-Einstein condensate — •Tilman Zibold, Matteo Fadel, Boris Décamps, and Philipp Treutlein — Department of Physics, University of Basel, Basel, Switzerland

We investigate the spatial entanglement in a spin squeezed Bose-Einstein condensate of rubidium atoms. By letting the atomic cloud expand and using high resolution absorption imaging we are able to access the spatial spin distribution of the many-body state. The observed spin correlations between different regions go beyond classical correlations and reveal spatial non-separability. Furthermore they allow for EPR steering of a subregion of the atomic spin. By inferring measurement outcomes of non-commuting observables in one region based on measurements in a separate region we are able to seemingly beat the Heisenberg uncertainty relation, realizing the EPR paradox with an atomic system. Our findings could be relevant for future quantum enhanced measurements of spatially varying observables such as electromagnetic fields.

Q 17.5 Mon 15:00 K 2.016

A coherent perfect absorber for matter waves — •Jens Benary[1], Andreas Müllers[1], Bodhaditya Santra[1], Christian Baals[1,2], Jian Jiang[1], Ralf Labouvie[1,2], Dmitry A. Zezyulin[3,4], Vladimir V. Konotop[4], 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 — [3]ITMO University, St. Petersburg 197101, Russia — [4]Centro de Física teórica e Computacional and Departamento de Física, Faculdade de Ciências, Universidade de Lisboa, Lisboa 1749-016, Portugal

A coherent perfect absorber is a system in which complete absorption of incoming radiation is achieved by a spatially localized absorber embedded in a wave-guiding medium. The concept of coherent perfect absorption (CPA) was introduced [1] for light interacting with absorbing scatterers. The phenomenon is based on the destructive interference of the transmitted and reflected waves. Extending the paradigm of CPA to nonlinear matter waves we find that the conditions for CPA can be achieved easier than in the linear case. This is due to the combination of a nonlinear medium with localized absorption stabilizing the system. We experimentally demonstrate CPA for matter waves with an atomic Bose-Einstein condensate of Rb-87 in a one-dimensional periodic potential with an absorbing lattice site. This absorption is tailored via an electron beam which locally induces losses.

[1] Y. D. Chong , L. Ge, H. Cao and A. D. Stone, Coherent Perfect Absorbers: Time-Reversed Lasers. Phys. Rev. Lett. 105 053901 (2010)

Q 17.6 Mon 15:15 K 2.016

Phase separation dynamics in a many-body Binary Bose-Einstein condensate — •Simeon Mistakidis[1], Garyfallia Katsimiga[1], Panagiotis Kevrekidis[2], and Peter Schmelcher[1,3] — [1]Zentrum für optische Quantentechnologien Luruper Chaussee 149 22761 Hamburg — [2]Department of Mathematics and Statistics, University of Massachusetts Amherst, Amherst, MA 01003-4515, USA — [3]The Hamburg Centre for Ultrafast Imaging, Universitat Hamburg, Luruper Chaussee 149, 22761 Hamburg, Germany

The many-body quenched dynamics of a binary mixture crossing the miscibility-immiscibility boundary and vice versa, is examine. Increasing the interspecies repulsion leads to the filamentation of the density of each component, involving shorter wavenumbers (and longer spatial scales) in the many-body approach. These filaments appear to be strongly correlated both at the one- and the two-body level, exhibiting domain-wall structures. Furthermore, following the reverse quench process dark-bright soliton trains are spontaneously generated and subsequently found to decay in the many-body scenario. We utilize single-shot images to provide a clean experimental realization of our current findings via which the filamentation process is clearly captured. To expose further the many-body nature of the observed dynamics direct measurements of the variance of single-shots are performed, verifying the presence of fragmentation but also the entanglement between the species.

Q 17.7 Mon 15:30 K 2.016

Approaching Steady-State Quantum Degeneracy — •Shayne Bennetts, Chun-Chia Chen, Rodrigo Gonzalez Escudero, Benjamin Pasquiou, and Florian Schreck — Institute of Physics, University of Amsterdam

So far BECs and atom lasers have only been demonstrated as the product of a time sequential, pulsed cooling scheme. Here we will describe a steady-state system demonstrating phase-space densities (PSD) approaching degeneracy. By flowing atoms through a series of spatially separated cooling stages and employing a range of novel tricks we recently demonstrated a steady-state strontium MOT with a PSD above 10^{-3} [1], 100 times higher than previous experiments. Now we demonstrate a set of tools, compatible with steady-state operation, to continuously cool and transfer microkelvin-cold atoms from a MOT into a dipole trap reservoir. Furthermore, by combining our novel machine architecture with a lighshift engineering technique we previously demonstrated [2], we protect a BEC from the strong fluorescence of a nearby MOT. Using all these tools on our high PSD MOT, quantum degeneracy in a steady-state system seems at reach. A steady-state source of degenerate atoms offers great advantages for applications such as next generation degenerate atomic clocks, super-radiant lasers or atom-interferometers for gravitational wave detection.

[1] S. Bennetts *et al.*, Phys. Rev. Lett. 119, 223202 (2017).
[2] S. Stellmer *et al.*, Phys. Rev. Lett. 110, 263003 (2013).

Q 17.8 Mon 15:45 K 2.016

Role of thermal phonon scattering for impurity dynamics in low-dimensional BEC — •Tobias Lausch, Artur Widera, and Michael Fleischhauer — TU Kaiserslautern and Forschungszentrum OPTIMAS, Erwin-Schroedinger-Strasse 46, 67663 Kaiserslautern, Germany

Ultracold gases have proven powerful systems to engineer quantum systems, paving the way for quantum simulations of solid state phenomena. An intriguing focus of research lies on impurity systems, aiming on elucidating microscopic properties of thermalization or quasi-particle formation in quantum systems.

We theoretically study the immersion of single impurities into a BEC in different spatial-dimensions and solve a Boltzmann equation to analyze the non-equilibrium dynamics. We find that high order scattering processes, such as two phonon scattering, dominate the impurities cooling dynamics in low dimensional BEC even at low (experimentally accessible) finite temperatures. In fact, these two-phonon scattering processes are the microscopic mechanism reflecting the famous Mermin-Wagner-Hohenberg theorem. Our work undelines the necessity to include higher-order scattering terms in the investigation of low-dimensional impurity physics.

Q 17.9 Mon 16:00 K 2.016

Prospects for studying atom-ion interaction with giant Rydberg atoms in a Bose-Einstein condensate — •Felix Engel, Kathrin Kleinbach, Thomas Dieterle, Carolin Dietrich, Robert Löw, Florian Meinert, and Tilman Pfau — 5. Physikalisches Institut, Universität Stuttgart, Germany

Giant Rydberg atoms immersed in ultracold quantum gases realize situations where thousands of ground-state atoms reside within the Rydberg electron orbit. In our experiments, we study the interaction of a single highly excited Rydberg electron ($n \sim 200$) with a Bose-Einstein condensate (BEC). The interaction of the Rydberg electron with the condensate atoms causes a density-dependent spectral line shift and broadening of the Rydberg excitation, which reflects the underlying scattering physics.

Using a tightly focused optical microtrap we access a parameter regime for which the Rydberg electron orbit largely exceeds the spatial extent of the BEC. This reduces the contribution of electron-neutral interaction with increasing n to the observed excitation spectrum. Consequently, the interaction of the condensate atoms with the Rydberg ionic core is expected to actively shape the spectral response, which provides an appealing route to study atom-ion interaction in a BEC.