Q 15: Ultracold atoms and BEC - II (with A)

Time: Monday 17:00–19:00 Location: N 1

Q 15.1 Mon 17:00 N 1

Multiple BECs in a non-degenerate ring cavity — •Deepak Pandey[1,3], Grigor Kuyumjyan[1], Walid Cherifi[1], Naik Devang[1], Andrea Bertoldi[1], Arnaud Landragin[2], and Philippe Bouyer[1] — [1]LP2N, Université Bordeaux, IOGS, CNRS, Talence, France — [2]LNE-SYRTE, Observatoire de Paris, CNRS, UPMC, F-75014 Paris, France — [3]Presently at Institut für Angewandte Physik, Wegelerstr. 8, D-53115 Bonn, Germany

Quantum degenerate gases of neutral atoms are excellent systems with important applications in the study of many body quantum physics, condensed matter physics, precision measurements, and quantum information processing. We demonstrate the creation of multiple ^{87}Rb Bose-Einstein condensates (BECs) in the higher transverse modes of a bow-tie ring cavity at telecom wavelength 1560 nm. The non-degenerate character of the cavity allows splitting and merging of cold ensembles by deforming the trapping potentials inside the cavity. Another cavity resonance at 780 nm will allow us to realize the cavity aided quantum non-demolition measurements to generate measurement induced spin squeezed states.

Q 15.2 Mon 17:15 N 1

Phase coherence and entanglement in Bose-Einstein condensates — •Tilman Zibold, Matteo Fadel, Roman Schmied, Baptiste Allard, Jean-Daniel Bancal, Nicolas Sangouard, and Philipp Treutlein — Department of Physics, University of Basel, Basel, Switzerland

We perform quantum enhanced metrology on an atom chip using internal states of Bose- Einstein condensed ^{87}Rb atoms. State dependent trapping potentials allow for the generation of entangled states such as squeezed states via interatomic interactions. By accounting for the atom number dependent phase shifts in the system we are able to produce strongly squeezed states. Our recent experiments demonstrate that these many-particle entangled states can exhibit Bell correlations [1]. We will discuss experiments on the limitations of phase coherence of squeezed atomic states and recent advances towards a Bell-test with split Bose-Einstein condensates.

[1] Schmied et al. Science 352, 441 (2016)

Q 15.3 Mon 17:30 N 1

supersolidity in a Bose-Einstein condensate — •Andrea Morales, Julian Leonard, Philip Zupancic, Tilman Esslinger, and Tobias Donner — 1Institute for Quantum Electronics, ETH Zürich, Switzerland

Supersolidity is a paradoxical state of matter featuring both the crystalline order of a solid and the dissipationless flow typical of a superfluid. The realization of this state of matter requires the breaking of two continuous symmetries, the phase invariance of a superfluid and the translational invariance to form the crystal. Proposed for Helium almost 50 years ago, experimental verification of supersolidity remained elusive. Here we report on the realization of such a supersolid state of matter.

This state is realized by coupling a Bose-Einstein condensate (BEC) to the modes of two crossed optical cavity modes. Self-organization to individual cavities only breaks a discrete spatial symmetry and realizes a *lattice supersolid*. By equally coupling the BEC to both modes we enhance the symmetry of the system to a continuous one and observe simultaneous self-organization to the two cavities. We measure the high ground state degeneracy of the new supersolid state by measuring the crystal position over many realizations through the light fields leaking from the cavities. We also monitor real time fluctuations in the crystal position by the relative change in the light levels.

Q 15.4 Mon 17:45 N 1

Realization of balanced gain and loss in a Bose-Hubbard model beyond the mean-field approximation — •Daniel Dizdarevic, Kirill Alpin, Johannes Reiff, Jörg Main, and Günter Wunner — 1. Institut für Theoretische Physik, Universität Stuttgart, Germany

In recent years there has been a growing interest in non-hermitian and especially $\mathcal{PT}$ symmetric quantum mechanics, since they allow for an effective description of open quantum systems. A quantum system exhibiting $\mathcal{PT}$ symmetry is given by a BEC in a double well with balanced particle gain and loss, which can be described in the mean-field limit by a Gross-Pitaevskii equation with a complex potential. Although a complex potential renders the Hamiltonian non-hermitian, $\mathcal{PT}$-symmetric stationary states with real eigenvalue spectra exist.

We present a possible experimental realization of such a system by embedding it into a hermitian time-dependent four-mode optical lattice, where additional potential wells act as reservoirs and particle exchange happens via tunneling [1]. Since particle influx and outflux have to be controlled explicitly, a set of conditions on the potential parameters is derived. In contrast to previous work, our focus lies on a full many-particle description beyond the mean-field approximation using a Bose-Hubbard model, where especially the differences arising are of interest. Furthermore, we examine whether $\mathcal{PT}$ symmetric stationary states still appear in the limit of low particle numbers.

[1] Kreibich et al., Phys. Rev. A 87, 051601(R) (2013)

Q 15.5 Mon 18:00 N 1

A Homogeneous 2D Fermi Gas — •Klaus Hueck, Niclas Luick, Lennart Sobirey, Jonas Siegl, Thomas Lompe, and Henning Moritz — Institut für Laserphysik, Universität Hamburg, Luruper Chaussee 149, 22761 Hamburg

Ultracold 2D Fermi gases in the BEC-BCS crossover provide a model system to investigate e.g. the Kosterlitz-Thouless transition to superfluidity. So far ultracold 2D Fermi gases have been studied in harmonic trapping potentials. This results in an inhomogeneous density distribution, which complicates the theoretical description of the system and only allows for the extraction of trap averaged quantities when utilizing non-local measurement methods such as time of flight imaging.

Here, we present our realization of an ultracold 2D Fermi gas trapped in a homogeneous disk-shaped potential. The radial confinement is realized by a ring-shaped blue-detuned beam with steep walls. Additionally a digital micro mirror device can be used to remove residual inhomogeneities and to imprint arbitrary repulsive potentials onto the system. This enables us to study systems in close analogy to e.g. gated 2D electron gases.

Q 15.6 Mon 18:15 N 1

Non-equilibium BCS state Fermi gas — Alexandra Behrle, Timothy Harrison, •Kuiyi Gao, Martin Link, and Michael Koehl — Physikalisches Institut, University of Bonn, Wegelerstrasse 8, 53115 Bonn, Germany

Ultracold Fermi gases with tunable interactions have been widely used to investigate the BEC-BCS crossover in the last decade and superfluidity of Fermi gases with different interactions have shown a variety of rich physics. So far, the focus of research has mainly been on the equilibrium state of an attractive gas of cooper pairs. Non-equilibrium coherent dynamics of the BCS state was proposed for studying collective modes, pair formation and excitations in superconductivity, however, experimental realization has been hindered by the difficulty of performing fast enough perturbations to the system. In this talk, we will show our efforts in preparing and detecting a non-equilibrium BCS-superfluid of fermionic 6Li atoms. We focus on the coherent dynamics with fast modulation and quenched interactions using fast ramps across the Feshbach resonance.

Q 15.7 Mon 18:30 N 1

Pairing in the normal phase of a 2D Fermi gas — •Puneet Anantha Murthy, Mathias Neidig, Ralf Klemt, Marvin Holten, Luca Bayha, Philipp Preiss, Gerhard Zürn, and Selim Jochim — Physikalisches Institut, Universitaet Heidelberg

Paring of fermions is central to our understanding of superfluidity and superconductivity. In their celebrated work, Bardeen, Cooper and Schrieffer (BCS) describe how a pairing instability at sufficiently low temperatures at the Fermi surface leads to a transition from the normal phase to a superfluid for a weakly attractive Fermi gas. The formation of these Cooper pairs is a true many-body effect as it requires the presence of a Fermi sea and according to the BCS theory the pairing starts at the transition temperature. On this poster, we present evidence for pairing also in the normal phase of a two component 2D Fermi gas. We use spatially resolved radio-frequency (RF) spectroscopy to measure the onset of pairing at different interaction strengths across the 2D BEC-BCS crossover. We show that pairing occurs at temperatures significantly higher than the critical temperature for superfluidity. The spatially resolved RF spectroscopy allows us to separate the low- from the high-density regions of our inhomogeneous trap. As a result, we can identify regions where two-body physics is applicable and regions where many body effects take over. We map out a region in the strongly interacting regime, where paring is significantly influenced by the many-body nature of the system and cannot be explained purely by two-body physics.

Q 15.8 Mon 18:45 N 1

Quantum Simulation of Mesoscopic Fermi Systems — •Philipp Preiss, Andrea Bergschneider, Vincent Klinkhamer, Jan-Hendrik Becher, Gerhard Zürn, and Selim Jochim — Universität Heidelberg, 69120 Heidelberg, Germany

Ultracold quantum gases in optical potentials have achieved spectacular progress in the experimental simulation of complex quantum systems. Complementary to many-body experiments, mesoscopic systems comprised of a small number of atoms offer the possibility to study highly entangled quantum states with an exceptional degree of versatility and control.

We are implementing a highly tunable platform to study such correlated few-fermion systems. As already demonstrated in our group, quantum states of 6Li atoms can be prepared with a deterministic atom number and spin configuration, and interactions are tunable via a magnetic Feshbach resonance. We are extending these techniques to a large range of trap geometries, including trap arrays as well as low-dimensional and toroidal systems. A novel readout scheme with single-particle and spin sensitivity allows us to measure spin- and momentum correlations.

The tunable few-fermion system will enable the realization of many novel mesoscopic systems, for example cylindrical optical lattices with unusual periodic boundary conditions. In two-dimensional traps, we will be able to study the formation of shell structure as well as the emergence of fermion pairing in the presence of interactions. I will discuss the status and prospects of our mesoscopic quantum simulator.