Q 27: Quantum Gases: Bosons IV

Time: Tuesday 14:30–16:30 Location: P/H2

Q 27.1 Tue 14:30 P/H2

Non-destructive detection of a BEC phase transition — •Romain Müller, Robert Heck, Aske Thorsen, Mario Napolitano, Mark Bason, Jan Arlt, and Jacob Sherson — Aarhus Universitet, Ny Munkegade 120, 8000 Aarhus Denmark

Quantum non-demolishing (QND) measurements of atomic ensembles- both at room and (ultra-)cold temperatures - have over the past decade proven to be a versatile tool for quantum information processing.

We have recently demonstrated that a QND variant, dark field Faraday imaging, is a valuable and simple tool for single shot characterization of experimental parameters such as trap frequencies and the ambient vector magnetic field [1]. In this work we expand these efforts to the domain of single shot characterization of quantum phase transitions; explicitly the transition from a thermal cloud to a BEC. This has previously been investigated phenomenologically in a single experiment [2] in which a series of in-situ pictures of the cloud allowed for the observation of the formation of the condensate. Since observation with high signal to noise is inherently associated with heating [1], it is crucial to have a detailed understanding of the destructivity imparted by the 'non-destructive' probing. This tradeoff is investigated in this work and we make a detailed comparison with the shape of the phase transition inferred using destructive TOF probing.

[1] Gajdacz et al., Rev. Sci. Instrum. 84, 083105 (2013)
[2] Miesner et al., Science, Vol. 279 no. 5353 pp. 1005-1007 (1998)

Q 27.2 Tue 14:45 P/H2

^{39}K and ^{87}Rb dual Bose-Einstein condensates: Production and Experiments — •Lars J. Wacker, Nils Byg Jørgensen, Nils Winter, Jacob F. Sherson, and Jan J. Arlt — Department of Physics and Astronomy, Aarhus University, Ny Munkegade 120, 8000 Aarhus C, Denmark

The effective interaction of ultracold atoms can be changed by several orders of magnitude by addressing magnetic Feshbach resonances. Varying the magnetic field hence also determines whether atoms are mutually attractive or repulsive.

This feature in combination with optical trapping allows us to produce ^{39}K BECs. ^{39}K also allows for tuning of its interaction with ^{87}Rb via interspecies resonances. Based on such an interspecies resonance, we have produced the first ^{39}K and ^{87}Rb dual BECs. This novel system opens up for many different research directions. We have been able to use the interspecies resonance to control the miscible/immiscible phase transition of the condensates.

Furthermore this allows studies of the Efimov effect. While originally considered in the context of three identical bosons in nuclear systems, it has more recently been observed in a system of cold atoms. Within our current work we investigate Efimov physics in a two species system, which provides insights beyond the original picture of three identical bosons.

Q 27.3 Tue 15:00 P/H2

Scaling behaviour in quantum quench dynamics — •Markus Karl[1,2], Aisling Johnson[2], Eike Nicklas[2], Markus Oberthaler[2], and Thomas Gasenzer[1,2] — [1]Institut für Theoretische Physik, Ruprecht-Karls-Universität Heidelberg, Philosophenweg 16, 69120 Heidelberg — [2]Kirchhoff-Institute for Physics, Ruprecht-Karls-Universität Heidelberg, Im Neuenheimer Feld 227, 69120 Heidelberg

We present results on scaling features which appear during the dynamical evolution of a quantum system as a consequence of a rapid parameter quench near a phase transition. We focus on a binary mixture of Rubidium-87 hyperfine states, in one spatial dimension, where the relative degrees of freedom can be mapped onto a system of collective spins. The strength of a Rabi coupling between the two hyperfine states controls a Ising-class quantum phase transition within the spin system. Here, we study quench dynamics by means of classical-statistical simulations and compare our results to Bogoliubov theory for the spin system and recent experimental data. Quenching the Rabi coupling to the vicinity of the quantum critical point, scale invariance of the spatial and temporal behaviour is observed, both theoretically and experimentally. Our data indicates that even far from thermal equilibrium universal behaviour corresponding to a stationary system can be identified. The theoretical findings suggest that close to the critical point of the spin system the energy introduced by the quench leads to a crossover behaviour reminiscent of the finite-temperature critical properties the Ising-class system.

Q 27.4 Tue 15:15 P/H2

Universal Dynamics in Finite-Temperature Unitary Bose Gases — •Ulrich Eismann[1,2,3], Lev Khaykovich[4], Igor Ferrier-Barbut[1], Sébastien Laurent[1], Benno S. Rem[1], Andrew T. Grier[1], Li-Chung Ha[2], Frédéric Chevy[1], Cheng Chin[2], and Christophe Salomon[1] — [1]LKB, ENS, UPMC, CNRS UMR 8552, 24 rue Lhomond, 75231 Paris, France — [2]JFI and Department of Physics, University of Chicago, Chicago, IL 60637, USA — [3]Now with TOPTICA Photonics AG, Lochhamer Schlag 19, 82166 Graefelfing, Germany — [4]Department of Physics, Bar-Ilan University, Ramat-Gan, 52900 Israel

The low temperature unitary Bose gas is a fundamental paradigm in few-body and many-body physics, attracting wide theoretical and experimental interest. We briefly introduce a theory describing the dynamic interplay of two-body evaporation and three-body recombination in a trapped unitary atomic gas. We identify a magic trap depth where, within some parameter range, evaporative cooling is balanced by the recombinational heating such that the gas temperature stays constant. We perform independent experiments with ^{133}Cs and ^{7}Li atoms tuned to Feshbach resonances. These fully support the predictions of the model and enable quantitative measurements of both the trap depth, and the 3-body recombination rate in the low-temperature domain. We verify the validity of the universal dynamics for both species, for 2D and 3D evaporation, over two orders of magnitude in temperature and four orders of magnitude in three-body loss.

Q 27.5 Tue 15:30 P/H2

Decay of dark solitary like wave phenomena in a disk shaped Bose-Einstein Condensate — •Nadine Meyer, Harry Proud, Marisa Perea, Charlotte O'Neale, Sebastian Riess, and Kai Bongs — School of Physics and Astronomy, University of Birmingham, Edgbaston, Birmingham, United Kingdom

The nonlinear wave phenomenon of solitons plays an important role in high speed optical communication and energy transport in molecular biology and is one of the fundamental excitations found in Bose-Einstein condensates following the nonlinear Gross-Pitaevski equation.

To our knowlegde we present the first experimental observation of quasi 2D soliton like excitations in a disk shaped Bose-Einstein condensate. The evolution, movement and decay of a dark spatial solitary wave phenomenon confined in an ultracold atomic system will be discussed. By using a spatial light modulator for optical imprinting, the quantum phase of the Bose-Einstein condensate can be arbitrarily engineered. This versatile method gives rise to a nonlinear particle like matterwave pulse where the dispersion of the soliton like excitation is balanced by the repulsive inter atomic interaction. In contrast to formerly performed experiments in elongated BEC traps the soliton like excitation created in the disk shaped Bose-Einstein condensate is dynamically unstable and decays rapidly within a few ms. The collapse observed in the experiment shows an even stronger accelerated decay in comparison to preliminary results of numerical simulations of the GPE. This might be due to thermodynamical instabilities and small anharmonicities in the trapping potential.

Q 27.6 Tue 15:45 P/H2

Measurements of phase coherence and excitation in finite temperature Bose-Einstein condensates — •Matteo Fadel, Baptiste Allard, Roman Schmied, and Philipp Treutlein — Department of Physics, University of Basel, Klingelbergstrasse 82, 4056 Basel, Switzerland

Atomic Bose-Einstein condensates (BECs) are highly controllable isolated quantum systems with long coherence times, and offer applications in metrology and quantum information processing. We experimentally prepare finite-temperature BECs, and measure their decoherence dynamics and excitation spectrum.

Our system consists of a two-component Rubidium-87 Bose-Einstein condensate, consisting of a few hundred atoms, created on an atomchip [1]. We modulate the trap position and frequency to prepare condensates at different temperatures, and use sideband Rabi spectroscopy to probe the excitation spectrum.

In finite-temperature BECs, interactions with the non-condensed fraction are predicted to limit the phase coherence [2]. We experimentally study these fundamental limits by performing Ramsey spectroscopy with BECs of different temperatures and densities.

[1] P. Boehi, et al., Nature Physics 5, 592 (2009).

[2] A. Sinatra, Y. Castin, and E. Witkowska, Phys. Rev. A 80, 033614 (2009).

Q 27.7 Tue 16:00 P/H2

Phase coherence of a Bose-Einstein condensed light field — •Julian Schmitt[1], Tobias Damm[1], David Dung[1], Christian Wahl[1], Frank Vewinger[1], Jan Klaers[1,2], and Martin Weitz[1] — [1]Institut für Angewandte Physik, Universität Bonn, Wegelerstraße 8, 53115 Bonn — [2]Institute for Quantum Electronics, ETH Zürich, Auguste-Piccard-Hof 1, 8093 Zürich

In many physical systems, transitions between different phases of matter are accompanied by a spontaneous breaking of symmetry, as e.g. spin orientation in magnets and the corresponding breaking of rotational invariance. An ideal gas of bosons features a phase transition to a Bose-Einstein condensate, where a macroscopic fraction of particles is described by the single-particle wave function of the lowest energy eigenstate along with a spontaneously chosen, fixed phase. First-order spatio-temporal correlations of Bose condensates have been studied in e.g. atomic gases and exciton-polaritons. However, in-situ monitoring of the phase diffusion of a condensed system has proven challenging. Here, we present time-resolved measurements of the phase evolution of a photon Bose-Einstein condensate in dye microcavity, as obtained from heterodyne interferometry using a frequency-stable dye laser as a local oscillator. For increasing condensate fractions, a drastic reduction of the condensate linewidth is observed and first-order coherence is established. Further, we can relate first to second-order coherence properties, which are determined by the grand canonical nature of the photon condensate.

Q 27.8 Tue 16:15 P/H2

Calorimetry of a Bose condensed photon gas — •Tobias Damm, Julian Schmitt, Qi Liang, David Dung, Christian Wahl, Frank Vewinger, Martin Weitz, and Jan Klaers — Institut für Angewandte Physik, Universität Bonn, Wegelerstr. 8, D-53115 Bonn

In earlier works of our group, a thermalized photon gas and a transition to a Bose-Einstein condensate of photons has been realized in a dye-filled optical microcavity. A number-conserving thermalization of the photon gas in this system is achieved by repeated absorption and emission processes of dye-molecules.

The dye-filled optical microcavity environment is a well suited system to study the behavior of Bose gases at its phase transition from the classical Boltzmann regime to the condensed phase. Here we report on the measurement of calorimetric properties of a nearly ideal Bose gas at this transition, determined by investigating the thermodynamic behavior of the two-dimensional photon gas near criticality. The measurements clearly reveal a singularity of the specific heat, shaped similar to the well known λ-transition from the fluid to superfluid state of liquid helium.