Q 29: Quantum Gases: Bosons III

Time: Wednesday 11:00–13:00 Location: e001

Group Report Q 29.1 Wed 11:00 e001

BEC Heidelberg: Exploring non-linear dynamics - from discrete to continuous — •Philipp Kunkel, Maximilian Prüfer, Daniel Linnemann, Helmut Strobel, Wolfgang Müssel, Christian-Marcel Schmied, Thomas Gasenzer, and Markus K. Oberthaler — Kirchhoff-Institut für Physik, Im Neuenheimer Feld 227, 69120 Heidelberg

Spinor Bose-Einstein condensates are ideally suited to study complex many-particle dynamics, as they offer a unique level of experimental control. Our experiments focus on spin-mixing as the non-linear mechanism coupling internal and external degrees of freedom. We study this interplay using spin-changing collisions in Rb-87 in quasi one-dimensional confinement in two different regimes. By tuning the longitudinal trap frequency we first generate a situation of only few accessible modes. In this situation the spin-changing collisions act on top of an effective potential. We use spin-mixing as a tool to probe this potential and experimentally observe the population of different spatial modes. The possibility of creating nonlocal entanglement in this controlled few spatial modes situation is investigated. Going into the continuous regime, Bogoliubov theory predicts unstable momentum modes, which are occupied due to the local creation of atom pairs with opposite momenta. Experimentally we find strong spatial correlations for short evolution times. For later times, irrespective of different initial conditions the dynamics are governed by many modes but nevertheless general features can be found. We identify emerging, long living structures correlating the collective spin and the total density.

Q 29.2 Wed 11:30 e001

Observation of the phononic Lamb shift in the Fröhlich model of a quantum impurity — •Fabián Olivares, Tobias Rentrop, Arno Trautmann, Fred Jendrzejewski, and Markus K. Oberthaler — Kirchhoff-Institut für Physik, Im Neuenheimer Feld 227, 69120 Heidelberg

The interaction of particles with fields can profoundly change their properties. Typical examples are Landau quasiparticles in metals or the QED electron mass renormalisation in vacuum. Ideally these complex phenomena can be studied best when the interaction strengths and particle confinement potentials are freely tuned. We engineer such a system, in which fermionic and bosonic impurities are immersed in a Bose-Einstein condensate (BEC). Its phonon field interacts with the impurities thus changing their effective parameters according to the Fröhlich polaron scenario. Using a dedicated spectroscopy method of Ramsey type we measure the energy shifts of confined impurities induced by the phonon-impurity interactions. These shifts cannot be explained by an effective mass concept alone, but only combined with a phonon-induced Lamb shift. The experimental observations are in excellent agreement with the theoretical expectation.

Q 29.3 Wed 11:45 e001

Dirty Bosons in a Quasi-One-Dimensional Harmonic Trap — •Tama Khellil[1], Antun Balaž[2], and Axel Pelster[3] — [1]Physics Department, Freie Universität Berlin, Germany — [2]Scientific Computing Laboratory, Institute of Physics Belgrade, University of Belgrade, Serbia — [3]Physics Department and Research Center OPTIMAS, Technische Universität Kaiserslautern, Germany

The emergence of a Bose-glass phase in a quasi one-dimensional Bose-Einstein-condensed gas in a harmonic trapping potential with an additional delta-correlated disorder potential at zero temperature is studied using two approaches [1]. At first, the corresponding time-independent Gross-Pitaevskii equation is numerically solved for the condensate wave function, and disorder ensemble averages are evaluated. With this we analyze quantitatively the emergence of mini-condensates in the local minima of the random potential, which occurs for weak disorder preferentially at the border of the condensate, while for intermediate disorder strength this happens in the trap center. Second, in view of a more detailed physical understanding of this phenomenon, we extend a quite recent non-perturbative approach towards the weakly interacting dirty boson problem, which relies on the Hartree-Fock theory and is worked out on the basis of the replica method, from the homogeneous case to a harmonic confinement [2].

[1] T. Khellil, A. Balaz, and A. Pelster, `arXiv:1510.04985`.
[2] T. Khellil and A. Pelster, `arXiv:1511.08882`.

Q 29.4 Wed 12:00 e001

Enhanced Quantum Simulation of Quantum Phase Transitions using Non-Destructive Measurements — •Robert Heck[1], Mark Bason[2], Ottó Elíasson[1], Romain Müller[1], Mario Napolitano[1], Aske R. Thorsen[1], Jan Arlt[1], and Jacob F. Sherson[1] — [1]Institute of Physics and Astronomy, Aarhus University, Denmark — [2]School of Physics and Astronomy, University of Nottingham, United Kingdom

In the age of quantum simulation, experiments must give as tight bounds as possible to guide the construction of theoretical models describing complex many-body quantum systems.

We report on three separate investigations using Faraday imaging, a method relying on the dispersive light-matter interaction: Firstly, we report that the shot-to-shot fluctuating initial conditions in the cold atomic cloud deterministically shift the transition point to a BEC. Then we demonstrate that precise knowledge of these initial conditions lead to enhanced precision in the determination of the transition point. Secondly, we probe the dynamics of the condensation process by repeated in-situ Faraday imaging of the same cloud. We quantify experimental sources of noise and demonstrate that the transition point depends on the number of probe photons in a deterministic manner. This is an important step towards the direct observation of the stochastic nature of the condensation process, due to bosonic stimulation. Finally, as a step towards single shot mapping of entire phase diagrams, we quasi-conservatively drive the transition to a BEC up to 30 times using repeated application of a tightly focused laser beam.

Q 29.5 Wed 12:15 e001

Formation of Jones-Roberts solitons in a flat Bose-Einstein condensate — •Nadine Meyer, Harry Proud, Jixun Liu, Charlotte O'Neale, Marisa Perea-Ortiz, Giovanni Barontini, and Kai Bongs — School of Physics and Astronomy, University of Birmingham, Edgbaston, Birmingham B152TT, United Kingdom

Nonlinear systems out of equilibrium give rise to vortex and soliton solutions that play an important role in high speed optical communication, energy transport mechanisms in molecular biology and astrophysics. Collective excitations are of special interest in this respect. However, plane solitons in 2D are intrinsically dynamical unstable, leaving the open question of reliable transport mechanism on surfaces in nature. The so-called Roberts solitons predicted in 1982 are part of the rich family of formstable soliton solutions with enhanced dynamical stability aspects regarding transport. In order to gain a deeper insight into these phenomena well controlled and flexible many body quantum systems at finite temperatures can be used for the simulation of these fundamental collective excitations of the nonlinear Gross-Pitaevski equation (GPE) and their dynamics. Here we employ phase imprinting methods for the first generation of these Jones Roberts solitons in ultracold gases of ^{87}Rb. By tailoring the optical imprint of a spatial light modulator (SLM), the quantum phase of the Bose-Einstein condensate can be arbitrarily engineered . The evolution and dynamics of Jones Roberts solitons prove them as long lived stable excitations travelling on extended surfaces.

Q 29.6 Wed 12:30 e001

Coupled Photon Condensates in Variable Trapping Potentials — •David Dung[1], Christian Kurtscheid[1], Tobias Damm[1], Julian Schmitt[1], Frank Vewinger[1], Jan Klärs[2], and Martin Weitz[1] — [1]Institut für Angewandte Physik, Universität Bonn — [2]Institut für Quantenelektronik, ETH Zürich

We report on recent work to create multiple coupled photon condensates in a single microcavity setup at room-temperature. Bose-Einstein condensation has been observed for cold atomic gases, solid state quasiparticles as exciton-polaritons, and more recently with photons. The latter can be realized in a dye-filled optical microcavity. Number-conserving thermalization of photons in the dye-microcavity is achieved by multiple absorption and fluorescence processes on dye-molecules. The short mirror spacing in the microcavity creates a suitable ground state for condensation, equivalent to a non-vanishing effective photon mass. By locally thermo-optically changing the refractive index inside the microcavity an effective trapping potential for photons can be induced. For this, a focused external control laser beam locally heats an absorbing silicon layer implemented below one of the cavity mirror coatings, leading to a local refractive index change of a thermo-responsive polymer mixed with the dye solution. The range of depths and trapping frequencies one can adjust with this technique have been determined. We also present measurements on photon tunneling between the microsites in the system. Moreover, a temporally retarded effective photon self-interaction is observed.

Q 29.7 Wed 12:45 e001

Phase and number correlations of Bose-Einstein-condensed light in a dye microcavity — •Julian Schmitt[1], Tobias Damm[1], David Dung[1], Christian Wahl[1], Frank Vewinger[1], Jan Klaers[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

Large statistical number fluctuations are a fundamental property known from the thermal behaviour of bosons, as has been revealed for both photons and material particles. In contrast to incoherent thermal ensembles, Bose-Einstein condensates can show both long-range phase coherence as well as damped intensity fluctuations. By examining the temporal interference of a Bose-Einstein condensate of photons in a dye microcavity, we observe the phase evolution and the emergence of temporal coherence of the photon condensate. In a Hanbury Brown-Twiss experiment, we identify a regime with large statistical intensity fluctuations, which are a consequence of grand-canonical statistical conditions realized by the photo-excitable dye molecules constituting both a particle and a heat reservoir. For small condensate sizes, we observe phase jumps of the condensate attributed to spontaneous symmetry breaking following condensate fluctuations to small photon numbers. For large systems, our experimental data shows phase coherence even in the presence of statistical number fluctuations. More recently, we have focussed on the study of the spatio-temporal correlations of the photon gas both in the thermal and the condensed phase.