Q 12: Quantum gases: Bosons I

Time: Monday 14:00–16:00 Location: E 001

Group Report Q 12.1 Mon 14:00 E 001

Intensity correlations of a Bose-Einstein condensate of photons in a dye-filled microcavity — •Julian Schmitt, Tobias Damm, David Dung, Cesar Cabrera, Frank Vewinger, Jan Klaers, and Martin Weitz — Institut für Angwandte Physik, Universität Bonn, Wegelerstraße 8, 53115 Bonn

We have measured second-order time correlations within a Bose-Einstein condensate of photons inside a dye-filled optical microcavity. In our experiment, photons are thermally equilibrated by multiple absorption-fluorescence cycles in a dye medium, which constitutes both a heat bath and a particle reservoir [1]. Due to the excitation exchange between the photon gas and the dye molecule reservoir, grand canonical experimental conditions are expected to be realized in the system [2]. Under these conditions, unusually large fluctuations of the condensate number (fluctuation catastrophe) are expected [3], where the photon number distribution is Bose-Einstein-like. We experimentally observe a bunching of the condensed photons, which we attribute as evidence for a grand canonical BEC regime. On the other hand, for large condensate fractions due to the finite size of the molecular reservoir a transition to the usual canonical condensate regime occurs, for which Poissonian number fluctuations lead to second order coherence. Our observations are in agreement with theoretical predictions.

[1] J. Klaers, J. Schmitt, F. Vewinger, M. Weitz, Nature **468**, 545(2010)
[2] J. Klaers, J. Schmitt, T. Damm, F. Vewinger, M. Weitz, Phys. Rev. Lett. **108**, 160403 (2012)
[3] e.g. R. Ziff, G. Uhlenbeck, M. Kac, Phys. Rep. **32**, 169 (1977)

Q 12.2 Mon 14:30 E 001

Non-Equilibrium Criticality of Driven Open Many-Body Quantum Systems — •Lukas M. Sieberer[1], Ehud Altman[2], Sebastian D. Huber[3], and Sebastian Diehl[1,4] — [1]Institute for Theoretical Physics, University of Innsbruck, 6020 Innsbruck, Austria — [2]Department of Condensed Matter Physics, Weizmann Institute of Science, Rehovot 76100, Israel — [3]Institute for Theoretical Physics, ETH Zurich, 8093 Zurich, Switzerland — [4]Institute for Quantum Optics and Quantum Information of the Austrian Academy of Sciences, 6020 Innsbruck, Austria

We investigate non-equilibrium phase transitions in an open bosonic many-body system with local single-particle incoherent pump and two-body loss. This model is naturally realized in a wide range of experimental contexts, such as cold atoms with optical Feshbach resonances or exciton-polariton condensates. Universal critical behavior in such a driven-dissipative system is characterized in three spatial dimensions by thermalization at low frequencies and the fadeout of reversible dynamics at long lengthscales according to a scaling law which features a new non-equilibrium critical exponent. We discuss prospects of probing this exponent in experiments.

Q 12.3 Mon 14:45 E 001

The quantum degenerate regime of driven ideal quantum gases in contact with a thermal bath — •Daniel Vorberg[1,2], Roland Ketzmerick[1,2], and André Eckardt[1] — [1]Max-Planck-Institut für Physik komplexer Systeme, Nöthnitzer Str. 38, 01387 Dresden — [2]Institut für Theoretische Physik, Technische Universität Dresden, 01062 Dresden

Time-periodically driven quantum systems (Floquet systems) that are weakly coupled to a thermal bath possess a time-periodic non-equilibrium steady state. This state is described by a density operator that is diagonal in the basis of Floquet states, that depends on the details of the coupling to the bath, and that generically violates detailed balance. We study ideal Floquet gases consisting of many non-interacting indistinguishable particles and investigate the influence of the bosonic or fermionic quantum statistic. To this end we consider generic one-dimensional model systems with regular and chaotic Floquet states and study their steady state using quantum-jump Monte Carlo simulations. We find that the density operator is generally not of Gaussian form, implying non-trivial occupation number correlations that deviate from Wick's decomposition. However, these deviations are found to be small and a mean-field theory based on a Gaussian ansatz still provides a good approximation to the exact steady state. We find quantum degenerate regimes where the respective quantum statistics leads to Bose condensation or the emergence of a Fermi edge.

Q 12.4 Mon 15:00 E 001

Environmentally induced dispersion of otherwise flat-band systems — •Albert Verdeny Vilalta and Andreas Mielke — Institut für Theoretische Physik, Universität Heidelberg, D-69120 Heidelberg, Germany

We investigate the experimental realization of bosonic condensed matter systems with a flat lowest energy band. Such systems can be obtained in optical lattices where shaking permits to engineer the hopping matrix element of the Bose Hubbard model. Since flat band systems are especially sensitive to perturbations, we consider the shaken Bose-Hubbard model coupled linearly to to a bosonic bath (driven Hubbard-Holstein model) so as to take environmental corrections into account. Using the flow equation method of infinitesimal unitary transformations, we construct the effective Hamiltonian of this system. We investigate the changes of its energy spectrum caused by the environment coupling and find a small dispersion as opposed to a perfectly flat band.

Q 12.5 Mon 15:15 E 001

Non-thermal fixed points in a two-component Bose gas across the miscible–immiscible transition — •Markus Karl[1,2], Boris Nowak[1,2], and Thomas Gasenzer[1,2] — [1]Institut für Theoretische Physik, Ruprecht-Karls-Universität Heidelberg, Philosophenweg 16, 69120 Heidelberg — [2]ExtreMe Matter Institute EMMI, GSI Helmholtzzentrum für Schwerionenforschung GmbH, Planckstraße 1, 64291 Darmstadt, Germany

We present a numerical analysis of non-thermal fixed points in an ultracold two-component Bose gas in two spatial dimensions across the miscible–immiscible transition. Unstable initial conditions are used to drive the system away from equilibrium, aiming for the excitation of topological defects such as domain structures and vortices, and their influence on the intermediate and late time evolution of the system is studied. Thereby a special focus is set on transient turbulent states, which are signaled by the emergence of quasi-stationary scaling laws in the occupation spectrum, $n(k) \sim k^{-\zeta}$. We find such quasi-stationary states far from equilibrium, so-called non-thermal fixed points, in all parameter regimes, *i.e.* in the miscible and the immiscible regime as well as at the transition point, accompanied by steady scaling laws with different scaling exponents, ζ, for the momentum distributions, which we are able to identify with the natural defect structures in the respective regimes.

Q 12.6 Mon 15:30 E 001

One-dimensional many-body quantum transport of Bose-Einstein condensates: a Truncated Wigner Approach — •Julien Dujardin[1], Arturo Argüelles[1], Alejandro Saenz[2], and Peter Schlagheck[1] — [1]Département de Physique, Université de Liège, 4000 Liège, Belgium — [2]Institut für Physik, Humboldt-Universität zu Berlin, 12489 Berlin, Germany

We study the transport properties of an ultracold gas of Bose-Einstein condensed atoms that is coupled from a magnetic trap into a one-dimensional waveguide. Our central motivation in the context of such guided atom lasers [1] is to explore the role of atom-atom interaction in many-body transport processes across finite scattering regions resembling tunnel junctions or quantum dots. Our theoretical approach to solve this problem is based on the Truncated Wigner Method [2] for which we assume the system to consist of two semi-infinite non-interacting leads and a finite interacting scattering region. The condensed and non-condensed fractions of the atomic density, the current, and the transmission in the steady-state regime are computed and compared with mean-field predictions as well as with numerical results obtained with the matrix-product state (MPS) method.

[1] W. Guerin et al., Phys. Rev. Lett. 97, 200402 (2006).
[2] C. W. Gardiner et al., J. Phys. B 35, 1555 (2002); A. Sinatra et al., J. Phys. B. 35, 3599 (2002) .

Q 12.7 Mon 15:45 E 001

Parametric resonance in Bose-Einstein condensates — Will Cairncross[1] and •Axel Pelster[2] — [1]Department of Physics, Queen's University at Kingston, Canada — [2]Fachbereich Physik, Technische Universität Kaiserslautern, Germany

We conduct a detailed stability analysis for Bose-Einstein condensates

(BECs) in a harmonic trap under parametric excitation by periodic modulation of the s-wave scattering length [1]. To this end we follow Ref. [2] and obtain at first equations of motion for the radial and axial widths of the condensate using a Gaussian variational ansatz for the Gross-Pitaevskii condensate wave function. Linearizing about the equilibrium positions, we obtain a system of coupled Mathieu equations, the stability of which has been studied extensively [3,4]. We carry out an analytic stability analysis for the Mathieu equations, and compare with numerical results for the nonlinear equations of motion. We find qualitative agreement between the Mathieu analytics and the nonlinear numerics, and conclude that the previously unstable (stable) equilibrium of a BEC might be stabilized (destabilized) by parametric excitation.

[1] W. Cairncross and A. Pelster, `arXiv:1209.3148`

[2] I. Vidanovic, A. Balaz, H. Al-Jibbouri, and A. Pelster, Phys. Rev. A **84**, 013618 (2011)

[3] J. Slane and S. Tragesser, Nonl. Dyn. Syst. Th. **11**, 183 (2011)

[4] J. Hansen, Arch. Appl. Mech. **55**, 463 (1985)