Q 20: Quantum gases: Bosons I

Time: Tuesday 10:30–12:15 Location: UDL HS2002

Group Report Q 20.1 Tue 10:30 UDL HS2002

Thermalization dynamics and the formation of a photon Bose-Einstein condensate emerging from a laser-like state — •Julian Schmitt, Tobias Damm, David Dung, Frank Vewinger, Jan Klaers, and Martin Weitz — Institut für Angewandte Physik, Universität Bonn, D-53115 Bonn, Deutschland

Dissipation and losses are known to be able to drive a physical system out of equilibrium. A prominent example for a system dominated by dissipative effects is the laser, where one engineers photon loss inside an optical resonator to achieve a large population of a selected resonator mode. This is in contrast to an ensemble thermalizing faster than that particles are lost, where thermodynamic equilibrium is reached and the system - under appropriate conditions - undergoes Bose-Einstein condensation (BEC) into the system ground state. Here we report a study of the thermalization dynamics of a photon gas trapped in a high-finesse dye microcavity, where thermal and chemical equilibrium is established by contact to the dye reservoir. We have carried out time-resolved measurements of the spatial and spectral photon dynamics with a streak camera. We find that the equilibration time is determined by the photon reabsorption time in the dye microcavity. Further, we observe the coherent oscillation of a laser-like wave packet inside the harmonic trap, which eventually collapses into a Bose-Einstein condensate as photons are reabsorbed and emitted by the dye molecules and reach thermal equilibrium. Our results show a dissipation-controlled crossover between a laser-like state and a photon BEC.

Q 20.2 Tue 11:00 UDL HS2002

Universality in the Heating Dynamics of 1D Ultracold Bosons — •Michael Buchhold[1] and Sebastian Diehl[1,2] — [1]Institute for Theoretical Physics, University of Innsbruck, A-6020 Innsbruck, Austria — [2]Institute for Quantum Optics and Quantum Information of the Austrian Academy of Sciences, A-6020 Innsbruck, Austria

Recent studies of heating and thermalization of interacting one-dimensional (1D) bosons in cold atom setups have triggered the general interest in non-equilibrium dynamics of bosons in lower dimensions. In the framework of a Keldysh path integral approach to describe non-equilibrium dynamics of a Luttinger Liquid, we investigate a 1D Bose gas subject to permanent heating.

We determine the universal scaling behavior of the phonon life-times, which differs from thermal equilibrium. This modifies the scaling of relevant experimental signatures, such as the dynamical structure factor or the density of states compared to a thermal state.

In order to trace the dynamics of thermalization processes and estimate the relevant time-scales of the heating dynamics, we compute the non-equilibrium phonon distribution function. This allows us for a separation of the universal non-equilibrium long-wavelength behavior from the short distance dynamics. The latter is dominated by thermal fluctuations with time-dependent, increasing temperature.

Q 20.3 Tue 11:15 UDL HS2002

Prethermalization in split one-dimensional Bose condensates — Tim Langen[3], •Sebastian Erne[1,2,3], Remi Geiger[3], Bernhard Rauer[3], Maximilian Kuhnert[3], Thomas Schweigler[3], Igor Mazets[3], Thomas Gasenzer[1,2], and Jörg Schmiedmayer[3] — [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 — [3]Vienna Center for Quantum Science and Technology (VCQ), Atominstitut, TU Wien, Vienna, Austria

The relaxation of nearly integrable systems is an interesting and open question. Nearly integrable systems are found to be trapped in a prethermalized state before relaxing to thermal equilibrium at a later stage. Under certain conditions these prethermalization plateaus are correctly predicted by a generalized Gibbs ensemble (GGE), however this presents the question of how many conserved quantities are necessary to accurately describe the state. We consider a coherently split one-dimensional Bose condensate, investigated via statistical simulations using the classical field equations. The time evolution is compared to experiments by T. Langen *et al.* at the Atominstitut in Vienna and the analytical predictions of the integrable Tomonaga-Luttinger liquid model and shows relaxation to a quasi-stationary state described by a GGE independent of the initial temperature prior to the splitting, connecting it to the non-thermal, steady state of the integrable system.

Q 20.4 Tue 11:30 UDL HS2002

Quantum Gases of Light in Variable Potentials — •David Dung, Tobias Damm, Julian Schmitt, Frank Vewinger, Jan Klärs, and Martin Weitz — Institut für Angewandte Physik, Universität Bonn

Bose-Einstein condensation, the macroscopic ground state occupation of bosonic particles at low temperature and high density, has previously been observed for cold atomic gases and solid state quasiparticles. In recent work, our group has realized Bose-Einstein condensation of photons in a dye-filled optical microcavity. In this experiment, a number conserving thermalization process is achieved by multiple absorption and fluorescence of dye-molecules. The microcavity modifies the photon dispersion and creates an effective trapping potential for photons. Formally, the system is equivalent to a two-dimensional gas of trapped, massive bosons.

We here report on current work to manipulate the environment of the photon gas by applying variable potentials. A trapping potential can be induced by locally changing the refractive index inside the microcavity. In the experiment this is realized by focused laser light that heats an absorptive thin film near the mirror surface. A thermo-responsive polymer mixed with the dye solution will undergo a phase-transition above a local temperature of 33°C and thereby change the refractive index significantly. The induced variable trapping potentials allow for the creation of multiple photon Bose-Einstein condensates on a lattice. More in the future, we plan to study topological phases and synthetic magnetic fields on the photonic lattice.

Q 20.5 Tue 11:45 UDL HS2002

Generalized Bose-Einstein condensation into multiple states in driven-dissipative systems — •Daniel Vorberg[1,2], Waltraut Wustmann[1,2], Roland Ketzmerick[1,2], and André Eckardt[1] — [1]Max-Planck-Institut für Physik komplexer Systeme, Nöthnitzer Str. 38, 01187 Dresden, Germany — [2]Technische Universität Dresden, Institut für Theoretische Physik, 01062 Dresden, Germany

Bose-Einstein condensation, the macroscopic occupation of a single quantum state, appears in equilibrium quantum statistical mechanics and persists also in the hydrodynamic regime close to equilibrium. Here we show that even when a degenerate Bose gas is driven into a steady state far from equilibrium, where the notion of a single-particle ground state becomes meaningless, Bose-Einstein condensation survives in a generalized form: the unambiguous selection of an odd number of states acquiring large occupations. Within mean-field theory we derive a criterion for when a single and when multiple states are Bose selected in a non-interacting gas. We propose a quantum switch for heat conductivity based on shifting between one and three selected states.

Q 20.6 Tue 12:00 UDL HS2002

Thermal ensembles evolved by Gravity-gradient potential — Luis Fernando Barragan-Gil, Oliver Gabel, and •Reinhold Walser — Institut für angewandte Physik, Technische Universität Darmstadt, Hochschulestr. 4a, 64289 Darmstadt

The realization of Bose-Einstein condensates in micro-gravity conditions, at the ZARM drop tower in Bremen by the QUANTUS collaboration [1,2] , has opened the possibility to measure corrections to local gravitational field of the Earth beyond the linear Earth's acceleration (g) [3,4]. This is known as the gravity gradient correction and it is the next dominan contribution found in classical newtonian physics as well as in general relativistic view of gravity.

We analyse a matter-wave interferometer for thermal ensembles [5], in the presence of the harmonic corrections to the gravitational potential, and look for the effect of temperature on the fringe pattern (i. e. reduction of contrast).

[1] Quantus Collaboration, http://www.iqo.unihannover.de/quantus.html

[2] van Zoest, T. et al, Bose-Einstein Condensation in Microgravity, Science, 328, 1540-1543 (2010)

[3] Dimopoulos, S. et al, General Relativistic effects in atom inter-

ferometry, Phys. Rev. D, 78 042003 (2008).
[4] Kasevich, M. A. and Chu, S., Atom Interferometry Using Stimulated Raman Transitions, Phys. Rev. D, 67, 181-184 (1991).
[5] Müntiga, H. et al, Interferometry with Bose-Einstein Condensates in Microgravity, PRL 110, 093602 (2013)