Q 27: Phase Transitions

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

Invited Talk Q 27.1 Wed 11:00 Aula

Engineering of many-body states in a driven-dissipative cavity QED system — Rodrigo Rosa-Medina[1], Fabian Finger[1], Nicola Reiter[1], Jakob Fricke[1], Panagiotis Christodoulou[1], Davide Dreon[2], Alexander Baumgärtner[1], Simon Hertlein[1], Justyna Stefaniak[1], David Baur[1], Dalila Rivero[1], Gabriele Natale[1], Tilman Esslinger[1], and •Tobias Donner[1] — [1]Institute for Quantum Electronics, ETH Zurich, 8093 Zurich, Switzerland — [2]PASQAL SAS, 7 Rue Leonard de Vinci, 91300 Massy, France

Exposing a many-body system to external drives and losses can fundamentally transform the nature of its phases, and opens perspectives for engineering new properties of matter. How such characteristics are related to the underlying microscopic processes is a central question for our understanding of materials. A versatile platform to address it are quantum gases coupled to the dynamic light fields inside optical resonators. This setting allows to create synthetic many-body systems with tunable, well-controlled dissipation channels, and at the same time to induce cavity-mediated long-range atom-atom interactions. By engineering the involved light field modes, we study in real-time the dynamics of a phase transition between two such crystals. When the dissipation via cavity losses and the coherent timescales are comparable, we find a regime of limit cycle oscillations leading to a topological pumping of the atoms. In a second set of experiments, we make use of the cavity-mediated interaction to induce the formation of pairs of correlated atoms. We demonstrate that this process is based on the amplification of vacuum fluctuations.

Q 27.2 Wed 11:30 Aula

Dissipative cooling of many-body states realized with Rydberg atoms — •Katharina Brechtelsbauer[1], Thierry Lahaye[2], Antoine Browaeys[2], and Hans Peter Büchler[1] — [1]Institute for Theoretical Physics III and Center for Integrated Quantum Science and Technology, University of Stuttgart, Pfaffenwaldring 57, 70569 Stuttgart, Germany — [2]Université Paris-Saclay, Institut d'Optique Graduate School, CNRS, Laboratoire Charles Fabry, 91127 Palaiseau Cedex, France

Dissipative preparation of quantum states offers a promising alternative to the adiabatic approach, which is often limited to small system sizes due to gap-closings near quantum phase transitions. In this work we propose a setup for preparing many-body states in systems of Rydberg atoms. The idea is to couple the system to a dissipative bath of additional Rydberg atoms via dipolar exchange interactions, such that the system is dissipatively driven into a certain stationary state. The selection of this final state is based on energy conservation, where the detuning between system and bath is tuned to ensure that the preferred decay channels are stronger than other ones. Depending on the exact form of the system-bath interactions the setup can be used to add excitations to the system or to cool into a certain system eigenstate while conserving the number of excitations.

Q 27.3 Wed 11:45 Aula

Phase transition and higher-order mean-field theory of chiral waveguide QED — •Kasper Jan Kusmierek[1], Max Schemmer[2], Sahand Mahmoodian[3], and Klemens Hammerer[4] — [1]Institute for Theoretical Physics, Leibniz University Hannover, Germany — [2]Istituto Nazionale di Ottica del Consiglio Nazionale delle Ricerche (CNR-INO), 50019 Sesto Fiorentino, Italy — [3]Centre for Engineered Quantum Systems, School of Physics, The University of Sydney, Sydney, NSW 2006, Australia — [4]Institute for Theoretical Physics, Leibniz University Hannover, Germany

Waveguide QED with cold atoms provides a potent platform for the study of non-equilibrium, many-body, and open-system quantum dynamics. Even with weak coupling and strong photon loss, the collective enhancement of light-atom interactions leads to strong correlations of photons arising in transmission. Here we apply an improved mean-field theory based on higher-order cumulant expansions to describe the experimentally relevant, but theoretically elusive, regime of weak coupling and strong driving of large ensembles. We determine the transmitted power, squeezing spectra and the degree of second-order coherence. In the regime of very large drive and atom numbers we observe an non-equilibrium phase transition. This reveals the important role of many-body and long-range correlations between atoms in steady state.

Q 27.4 Wed 12:00 Aula

Transition between Directed Percolation and Mean Field Universality in a driven, dissipative Rydberg gas — •Simon Ohler, Daniel Brady, and Michael Fleischhauer — RPTU Kaiserslautern, Erwin-Schrödinger-Str. 46, 67663 Kaiserslautern

The spread of excitations in a laser driven gas of Rydberg atoms under facilitation conditions bears many similarities to epidemics. Increasing the drive strength, a non-equilibrium phase transition from an absorbing to an active phase occurs. We analyze the dynamics of the Rydberg many-body system in the facilitation regime close to the critical point as a function of the gas temperature by means of Monte-Carlo simulations. While at very low temperatures the phase transition belongs to the directed percolation universality class, the dynamical critical exponent crosses over into a mean field behavior with increasing temperature, reminiscent of anomalous directed percolation. Additionally, we consider the avalanche-like spread of excitation cascades. For all temperatures the system exhibits power-law distributed avalanche sizes, which are key signatures of self-organized criticality, a process believed to lie at the heart of many critical phenomena in nature.

Q 27.5 Wed 12:15 Aula

Nanomechanically-induced quantum phase transition to a self-organized density-wave BEC — •Milan Radonjić[1,2], Leon Mixa[1], Axel Pelster[3], and Michael Thorwart[1] — [1]I. Institute of Theoretical Physics, University of Hamburg, Germany — [2]Institute of Physics Belgrade, University of Belgrade, Serbia — [3]Physics Department and Research Center OPTIMAS, University Kaiserslautern-Landau, Germany

We study nonequilibrium quantum phase transition (NQPT) in a hybrid quantum many-body system consisting of a vibrational mode of a nanomembrane interacting optomechanically with a cavity, whose output light couples to two internal states of an ultracold Bose gas held in an external quasi-1D box potential. For small effective membrane-atom couplings, the system is in a homogeneous BEC ground state, with no membrane displacement. Depending on the transition frequency between the two internal atomic states, either one or both internal states are occupied. By tuning the two couplings outside the respective critical regions, the system transitions to a symmetry-broken self-organized BEC phase, which is characterized by a sizeably displaced membrane and density-wave-like BEC profiles. This NQPT is both discontinuous and continuous for a certain interval of transition frequencies, and purely discontinuous outside of it.

Q 27.6 Wed 12:30 Aula

Low-energy modes in a trapped dipolar supersolid — •Paul Uerlings[1], Jens Hertkorn[1], Kevin Ng[1], Fiona Hellstern[1], Lucas Lavoine[1], Ralf Klemt[1], Tim Langen[1,2], and Tilman Pfau[1] — [1]5. Physikalisches Institut and Center for Integrated Quantum Science and Technology IQST, Universität Stuttgart — [2]Atominstitut, TU Wien, Stadionallee 2; 1020 Vienna, Austria

A supersolid is a phase of matter that combines the crystal-like periodic density modulation of a solid with the frictionless flow of a superfluid, simultaneously breaking both the global U(1) gauge symmetry and the translational symmetry. Breaking these two symmetries gives rise to two types of collective modes, called the Nambu-Goldstone and amplitude Higgs mode. We theoretically and experimentally investigate the excitation spectrum of a trapped dipolar quantum gas across the Bose-Einstein condensate to supersolid phase transition. In order to experimentally observe these excitations, we prepare a ultracold quantum gas of ^{162}Dy in an optical dipole trap with variable geometry. We compare our experimental results to numerical simulations of the extended Gross-Pitaevskii equation and the Bogoliubov-de-Gennes equations. The observed low-energy modes reveal the existence of the two distinct amplitude Higgs and Nambu-Goldstone modes that emerge in our system at the phase transition point. Our findings extend earlier work on the obervation of the Nambu-Goldstone mode and theoretical predictions on the amplitude Higgs mode.

Q 27.7 Wed 12:45 Aula

Observation of spatial first-order coherence in an optical

quantum gas in a box — •Leon Espert Miranda, Andreas Redmann, Kirankumar Karkihalli Umesh, Frank Vewinger, Martin Weitz, and Julian Schmitt — Institut für Angewandte Physik, Universität Bonn, Wegelerstraße 8, 53115 Bonn, Germany

The emergence of long-range correlations that span the entire system is a manifestation of phase transitions between different states of matter. Experimentally, such field correlations in quantum gases can be obtained by investigating the degree of first-order spatial coherence, for example, in interference experiments. Here we report a measurement of the build-up of quasi long-range correlations in a two-dimensional optical quantum gas trapped inside a box potential as the total number of particles in the gas is increased. The correlation information is obtained by measurements of the photon gas distribution in momentum space as well as interferometry of the dye-filled optical microcavity emission. We observe different scalings of the coherence length for the normal and quantum degenerate gas. Moreover, by studying different sizes of the box trap, we demonstrate that Bose-Einstein condensation sets in as soon as the coherence length exceeds the system size.