Q 52: Quantum Gases (Bosons) V

Time: Thursday 14:00–16:00 Location: S HS 037 Informatik

Q 52.1 Thu 14:00 S HS 037 Informatik

Self-organization of a BEC with competing polarizations — •Xiangliang Li, Andrea Morales, Alexander Baumgärtner, Philip Zupancic, Davide Dreon, Tobias Donner, and Tilman Esslinger — ETH Zürich, Switzerland

The coupling of a transversally pumped Bose-Einstein condensate (BEC) with a single optical cavity mode is known to exhibit a self-ordered phase with superradiant scattering of the photons into the cavity. Coupling BECs with multiple optical cavity modes is predicted to drive intriguing phases and realize novel quantum matter.

In our recent experiment, a BEC of 87Rb is placed inside the mode of a birefringent optical cavity and pumped transversally by a linearly polarized optical lattice. The scalar and vectorial atom-light couplings with the two polarization modes drive superradiant phase transitions into these two modes, respectively. Moreover, the coupling to one of the two modes can be controlled by changing the orientation of a magnetic field in space. We characterize the system by measuring the phase diagram for different magnetic field configurations, and provide a theoretical model.

Q 52.2 Thu 14:15 S HS 037 Informatik

Cavity-induced spin-orbit coupling in an interacting bosonic wire — •Catalin-Mihai Halati[1], Ameneh Sheikhan[1,2], and Corinna Kollath[1] — [1]HISKP, University of Bonn, Nussallee 14-16, 53115 Bonn, Germany — [2]Department of Physics, Shahid Beheshti University, G.C., Evin, Tehran 19839, Iran

We consider theoretically ultra-cold interacting bosonic atoms confined to a one-dimensional wire geometry and coupled to the field of an optical cavity. The spin-orbit coupling is induced dynamically via Raman transitions employing a cavity mode and a transverse running wave pump beam. By adiabatic elimination of the cavity field we obtain an effective Hamiltonian for the atomic degrees of freedom, with a self-consistency condition. We map the spin-orbit coupled bosonic wire to a bosonic ladder in a magnetic field, by discretizing the spatial dimension. Using the numerical density matrix renormalization group method, we show that the dynamical stabilization of a Meissner superfluid is possible in the continuum limit and thermodynamic limit.

Q 52.3 Thu 14:30 S HS 037 Informatik

Photon scattering in the dark – atomic self-organization in optical cavities with repulsive potentials — •Philip Zupancic, Xiangliang Li, Alexander Baumgärtner, Andrea Morales, Davide Dreon, Tilman Esslinger, and Tobias Donner — ETH Zurich, Institute for Quantum Electronics

Atomic self-organization in optical cavities has been demonstrated to occur when atoms are illuminated with a standing-wave pump beam that is red-detuned with respect to an atomic transition. The atoms order into a pattern that maximizes their scattering amplitude into the cavity mode. Can the same happen for a blue-detuned (i.e. repulsive) pump in which the atoms are confined to the field nodes that should suppress their scattering rate?

We experimentally demonstrate self-organization for repulsive standing-wave pumps and explain the physical mechanism. We observe two distinct self-ordered phases that we can tune to compete with each other, and fast time dynamics linked to the dynamic dispersive shift. One of the ordered phases shows a finite extent in the parameter space of pump power and detuning arising from competing energy scales.

Q 52.4 Thu 14:45 S HS 037 Informatik

Metastable states of ultracold atomic gases in cavity quantum electrodynamics — •Lukas Himbert[1], Cecilia Cormick[2], Rebecca Kraus[1], Shraddha Sharma[1], and Giovanna Morigi[1] — [1]Theoretical Physics, Saarland University, Campus E2.6, D-66123 Saarbrücken, Germany — [2]IFEG, CONICET and Universidad Nacional de Còrdoba, Ciudad Universitaria, X5016LAE Córdoba, Argentina

We investigate the stationary phases of the extended Bose-Hubbard model with infinite long-range interactions. This model describes ultracold bosonic atoms confined by a two-dimensional optical lattice and dispersively coupled to a cavity mode with the same wavelength as the lattice. The competition between tunneling, onsite interactions, and the long-range interactions mediated by the cavity photons gives rise to a rich ground-state phase diagram, which exhibits Mott-insulator, superfluid phases, lattice super solid, and matter-density waves. We perform a mean-field analysis of the grand-canonical ensemble and compare our analytical and numerical predictions for the ground state phase diagram with the results reported so far in the literature. We then determine the phase diagram for a class of incompressible metastable states as a function of the strength of the cavity-induced long-range interactions and discuss these findings in connection to the relaxation dynamics observed after quenches across the critical lines.

Q 52.5 Thu 15:00 S HS 037 Informatik

Entanglement Entropy for extended Bose Hubbard model — •Shraddha Sharma[1], Rebecca Kraus[1], Astrid E. Niederle[2], and Giovanna Morigi[1] — [1]Theoretical Physics, Saarland University, Campus E2.6, D–66123 Saarbrucken, Germany — [2]Fraunhofer Institute for Experimental Software Engineering IESE, 67663 Kaiserslautern, Germany and

We consider a bosonic gas in a two-dimensional optical lattice. The atoms interact via s-wave scattering and via long range interactions induced by the coupling with a cavity. We determine the phase diagram when the optical lattice wavelength is incommensurate with the cavity mode wavelength using a mean-field ansatz. In this regime we observe, in addition to the Mott-insulator and the superfluid, also a Bose-Glass and a superglass phase, where the density distribution supports the formation of a stable intracavity field. Using the slave-boson approach, we probe the effect of pumping on entanglement and density-correlation.

Q 52.6 Thu 15:15 S HS 037 Informatik

Dissipation induced structural instability in a quantum gas — •Katrin Kröger, Nishant Dogra, Manuele Landini, Lorenz Hruby, Francesco Ferri, Tobias Donner, and Tilman Esslinger — Institute for Quantum Electronics, ETH Zurich, 8093 Zurich, Switzerland

Dissipation is an intrinsic part of any physical system and can cause undesired effects of decoherence or act as a weak perturbation to the Hamiltonian dynamics. Currently, the concept of reservoir engineering is gaining more attention, which comprises the idea that properly designed dissipation channels can play a beneficial role by enabling steady state non-equilibrium phases and novel phase transitions. The construction of these dissipation channels in a quantum many-body system is however challenging due to the many degrees of freedom present and the sophisticated baths required. Here, we experimentally realize a synthetic quantum many-body system with controllable competing unitary and dissipative interactions based on a spin mixture of ultracold Rb87 atoms coupled to an optical cavity. Two orthogonal quadratures of the cavity mode are coherently coupled to two different spatial modes of the atomic system and the finite cavity loss mediates a dissipative chiral coupling between the different spatial modes. We study the emergence and characteristics of a non-stationary state and develop a simple two mode model to explain our observations. Interestingly, the physics can be mapped on the classical concept of a structural instability induced by dissipation.

Q 52.7 Thu 15:30 S HS 037 Informatik

Decay-dephasing-induced steady states in bosonic Rydberg-excited quantum gases in an optical lattice — •Mathieu Barbier[1], Andreas Geissler[1,2], and Walter Hofstetter[1] — [1]Institut für Theoretische Physik, Goethe Universität, 60438 Frankfurt am Main, Germany — [2]Laboratory of Quantum Physics, 67083 Université de Strasbourg, France

We investigate the possibility of realizing supersolid quantum phases in bosonic Rydberg-excited quantum lattice gases in the presence of non-unitary processes, by simulating the dynamical evolution starting from initial preparation in non-dissipative equilibrium states. Within Gutzwiller theory, we first analyze the many-body ground-state of a bosonic Rydberg-excited quantum gas in a two dimensional optical lattice for variable atomic hopping rates and Rabi detunings. Furthermore, we perform time evolution of different supersolid phases using the Lindblad-master equation. With the inclusion of two different non-unitary processes, namely spontaneous decay from a Rydberg state to the ground state and dephasing of the addressed Rydberg state, we study the effect of non-unitary processes on those quantum phases and observe long-lived states in the presence of decay and dephasing. We find that long-lived supersolid quantum phases are observable within a range of realistic decay and dephasing rates, while high rates cause any initial configuration to homogenize quickly, preventing possible supersolid formation.

Q 52.8 Thu 15:45 S HS 037 Informatik

Superradiant phases of a quantum gas in a bad cavity — •Simon B. Jäger[1], John Cooper[2,3], Murray J. Holland[2,3], and Giovanna Morigi[1] — [1]Theoretische Physik, Universität des Saarlandes, D-66123 Saarbrücken, Germany — [2]JILA, National Institute of Standards and Technology and Department of Physics, University of Colorado, Boulder, Colorado 80309-0440, USA — [3]Center for Theory of Quantum Matter, University of Colorado, Boulder, Colorado 80309, USA

We theoretically analyse superradiant emission of light from an ultracold gas of bosonic atoms confined in a bad cavity. The atoms dipolar transition which couples to the cavity is metastable and is incoherently pumped, the atomic motion is affected by the mechanical forces of the cavity standing-wave. By means of a mean-field model we determine the conditions on the cavity parameters and pump rate that lead to steady-state superradiant emission. We show that this occurs when the superradiant decay rate exceeds a threshold determined by the recoil energy, which scales the quantum atom-photon mechanical interactions. When this occurs, superradiant emission is accompanied by the formation of matter-wave gratings that diffract the emitted photons. The stability of these gratings is warranted when the pump rate is larger than a second threshold, below which the emitted light is chaotic. These dynamics are generated by collective quantum interference in a driven-dissipative system. It presents signatures of a peculiar second-order phase transition, where coherent phases of both light and matter emerge and are controlled by entirely incoherent processes.