Q 6: Quantum Gases: Bosons I

Time: Monday 14:30–16:30 Location: P 204

Q 6.1 Mon 14:30 P 204

The Space Atom Laser - A novel source for ultra-cold atoms in microgravity — •Matthias Meister, Albert Roura, Wolfgang P. Schleich, and The QUANTUS Team — Institut für Quantenphysik and Center for Integrated Quantum Science and Technology (IQST), Universität Ulm

The atom laser [1] is a unique device among the broad variety of applications of Bose-Einstein condensation (BEC) and transfers magnetically trapped atoms to an untrapped state. On ground the outcoupled atoms are dragged down by gravity resulting in an accelerated, directed beam. In microgravity, however, there is no favored direction and the only driving force of the dynamics is the repulsive interaction between the particles. Thus, the outcoupled atoms propagate away from the remaining trapped atoms and form a slowly expanding shell.

We present a protocol that allows the generation of such an unusual arrangement of atoms in microgravity by applying radio frequency outcoupling methods to a magnetically trapped BEC. In order to find a suitable scheme for an experimental implementation aboard the ISS using NASAs Cold Atom Laboratory we have thoroughly studied this process with the help of numerical simulations based on coupled Gross-Pitaevskii equations.

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[1] Phys. Rev. Lett. **78**, 582 (1997); Science **283**, 1706 (1999); Phys. Rev. Lett. **82**, 3008 (1999);

Q 6.2 Mon 14:45 P 204

Lowest-Lying Collective Frequencies of a Photon BEC in Presence of Temporally Retarded Interaction — •Enrico Stein and Axel Pelster — Fachbereich Physik und Forschungszentrum OPTIMAS, Technische Universität Kaiserslautern, Germany

Usually, collective mode frequencies of BECs are theoretically described for an instantaneous two-particle interaction between the bosons. Recent experiments on photon BECs show, however, that the effective photon-photon interaction is significantly influenced by memory effects which are presumably due to diffusion processes [1,2]. Therefore, we analyse the lowest-lying collective modes of a two-dimensional BEC in presence of a temporally retarded interaction by solving the underlying Gross-Pitaevskii equation with a variational approach [3]. We find that the frequencies for both the breathing and the quadrupole mode are shifted for a few percent with respect to a non-retarded two-particle interaction. Furthermore, we find the same order of magnitude for the violation of the Kohn theorem [4], i.e. the dipole-mode frequency differs from the trap frequency. Finally, we discuss how these retardation effects can be enhanced in an anisotropic harmonic confinement. All these findings are essential for determining the photon-photon interaction strength from measuring the lowest-lying collective frequencies of the photon BEC.

[1] J. Klaers, et al., Appl. Phys. B **105**, 17 (2011)
[2] J. Schmitt, et al., Phys. Rev. A **92**, 011602(R) (2015)
[3] V.M. Perés-Garciá, et al., Phys. Rev. Lett. **77**, 5320 (1996)
[4] A.L. Fetter and D. Rokhsar, Phys. Rev. A **57**, 1191 (1998)

Q 6.3 Mon 15:00 P 204

Strongly anomalous non-thermal fixed point in a quenched two-dimensional Bose gas — •Markus Karl[1,2] and Thomas Gasenzer[1,2] — [1]Kirchhoff-Institut für Physik, Ruprecht-Karls-Universität Heidelberg, Im Neuenheimer Feld 227, 69120 Heidelberg — [2]ExtreMe Matter Institute EMMI, GSI Helmholtzzentrum für Schwerionenforschung GmbH, Planckstraße 1, 64291 Darmstadt, Germany

Universal scaling behaviour in the relaxation dynamics of an isolated two-dimensional Bose gas is studied by means of semi-classical stochastic simulations of the Gross-Pitaevskii model. The system is quenched far out of equilibrium by imprinting vortex defects into an otherwise phase-coherent condensate. A strongly anomalous non-thermal fixed point is identified, signalled by a universal scaling form for the time-dependent occupation spectrum at late times. The fixed point is associated with a slowed power-law decay of the defects in the case that the dissipative coupling to the thermal background noise is suppressed. Interpreting our results in the context of phase-ordering kinetics and coarsening dynamics, we find numerical evidence for a new type of defect-ordering process far from equilibrium. This process is characterised by a large dynamical critical exponent $z = 5$, implying an anomalously slow algebraic progress of the system towards thermal equilibrium, and is distinctly different from coarsening within known near-equilibrium universality classes.

Q 6.4 Mon 15:15 P 204

Driven Bose-Hubbard Model with a Parametrically Modulated Harmonic Trap — Niklas Mann[1], •M. Reza Bakhtiari[1], Francesco Massel[2], Axel Pelster[3], and Michael Thorwart[1,4] — [1]I. Institut für Theoretische Physik, Universität Hamburg, Germany — [2]Department of Physics and Nanoscience Center, University of Jyväkylä, Finland — [3]Fachbereich Physik und Forschungszentrum OPTIMAS, Technische Universität Kaiserslautern, Germany — [4]The Hamburg Centre for Ultrafast Imaging, Germany

We investigate a periodically driven one-dimensional Bose-Hubbard model, where the global harmonic trap is parametrically modulated. The delicate interplay of both the local atom interaction and the global driving allows to control the dynamical stability of the trapped quantum many-body state. This mechanism is illustrated for weak atom interaction by solving the discretized version of the Gross-Pitaevskii equation within a Gaussian variational ansatz, yielding to a Mathieu equation for the condensate width. With this it turns out that the parametric resonance condition can be tuned with the atom interaction strength. For stronger interactions, this mechanism is confirmed by applying the numerically exact time-evolving block decimation scheme. Furthermore, we show that the global periodic modulation induces for large enough driving frequencies an effective time-independent local hopping strength for the atom gas.

Q 6.5 Mon 15:30 P 204

Continuous and discontinuous dark solitons in polariton condensates — •Stavros Komineas[1,2], Stephen Shipman[3], and Stephanos Venakides[4] — [1]University of Crete, Heraklion, Crete, Greece — [2]RWTH Aachen University, 52056, Aachen, Germany — [3]Louisiana State University, Baton Rouge, Louisiana 70803, USA — [4]Duke University, Durham, North Carolina 27708, USA

Bose-Einstein condensates of exciton-polaritons are described by a Schroedinger system of two equations for the wavefunctions of the excitons and the photons. The system is nonlinear due to exciton interactions. We have calculated all non-traveling soliton solutions for the one-dimensional lossless system. We will present in detail the frequency bands of dark soliton solutions. For positive detuning (photon frequency higher than exciton frequency), there is a frequency band for which the exciton wavefunction becomes discontinuous when the operating frequency exceeds the exciton frequency. The exciton wavefunction is discontinuous at its symmetry point, where it undergoes a phase jump of pi. A band of ordinary (continuous) dark solitons merges with the band of discontinuous dark solitons, forming a larger band over which the soliton far-field amplitude varies from 0 to infinity.

This phenomenon lies outside the parameter regime of validity of the Gross-Pitaevskii (GP) model. Within its regime of validity, we give a derivation of a single-mode GP model from the initial Schroedinger system and compare the continuous polariton solitons and GP solitons using the healing length notion.

Q 6.6 Mon 15:45 P 204

Measuring the Edwards-Anderson parameter in a disordered Bose-Hubbard model — •Antonio Rubio-Abadal[1], Jae-yoon Choi[1], Johannes Zeiher[1], Simon Hollerith[1], Sebastian Hild[1], Immanuel Bloch[1,2], and Christian Gross[1] — [1]Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Straße 1, 85748 Garching, Germany — [2]Fakultät für Physik, Ludwig-Maximilians-Universität München, Schellingstraße 4, 80799 München, Germany

Quantum gas microscopes provide exciting perspectives to study disordered systems, since short-range-correlated disorder potentials can be generated, and microscopic observables probed with single-site resolution. A recent theory study [1] points out that such a setup could be used to probe the disordered Bose-Hubbard (BH) model by measuring an analogue of the Edwards-Anderson (EA) parameter, a commonly adopted ”order parameter” in the context of spin glasses. Here we report on the direct measurement of the analogue EA parameter in disordered BH systems. We find a non-vanishing value in between the Mott lobes, indicating the presence of a Bose glass. These regions grow with disorder strength as expected. Our measurements provide a chemical-potential-resolved characterization of the phase diagram of the disordered BH model.

[1] S.J. Thomson et al. Phys. Rev. A 94, 051601(R) (2016)

Q 6.7 Mon 16:00 P 204

Realization of a Bose-Hubbard model with cavity-mediated global-range interactions — •Nishant Dogra[1], Renate Landig[2], Lorenz Hruby[1], Katrin Kröger[1], Manuele Landini[1], Rafael Mottl[1], Ferdinand Brennecke[3], Sebastian Huber[4], Tobias Donner[1], and Tilman Esslinger[1] — [1]HPF D4, Quantum Optics Group, Institute for Quantum Electronics, ETH Zurich,Otto-Stern-Weg-1,Zurich-8093 — [2]Department of Physics, Harvard University, Cambridge, Massachusetts 02138, USA — [3]Physikalisches Institut, Universität Bonn, Wegelerstrasse 8, Bonn-53115 — [4]HIT K 23.4, Institute for Theoretical Physics, ETH Zurich, Wolfgang-Pauli-Strasse 27, Zurich-8093

We experimentally realize a lattice model with cavity-mediated global-range interactions using a Bose-Einstein condensate (BEC). The global-range interactions are created by coupling the BEC to a single mode of a high-finesse cavity and illuminating it with a transverse laser-field. Their strength can be controlled by tuning the relative frequency of the transverse laser and the cavity. The presence of three competing energy scales- tunnelling, short-range interactions and global-range interactions gives rise to a rich phase diagram. We observe four different phases- a superfluid, a supersolid, a Mott insulator and a charge density wave. We also theoretically investigate the various features of our system within a mean-field framework which provides more insight about the nature of transitions between different phases.

Q 6.8 Mon 16:15 P 204

Observation of Four-body Ring-exchange Interaction and Anyonic Fractional Statistics — •Han-Ning Dai[1,2,3], Bing Yang[1,2,3], Andreas Reingruber[2,5], Hui Sun[1,3], Xiao-Fan Xu[2], Yu-Ao Chen[1,3,4], Zhen-Sheng Yuan[1,2,3,4], and Jian-Wei Pan[1,2,3,4] — [1]Hefei National Laboratory for Physical Science at Microscal and Department of Modern Physics, University of Science and Technology of China, Hefei, Anhui 230026, China — [2]Physikalisches Institut, Ruprecht-Karls-Universität Heidelberg, Im Neuenheimer Feld 226, 69120 Heidelberg, Germany — [3]CAS Center for Excellence and Synergetic Innovation Center in Quantum Information and Quantum Physics, University of Science and Technology of China, Hefei, Anhui, 230026, China — [4]CAS-Alibaba Quantum Computing Laboratory, Shanghai 201315, China — [5]Department of Physics and Research Center OPTIMAS, University of Kaiserslautern, Erwin-Schroedinger-Strasse, Building 46, 67663 Kaiserslautern, Germany

We report the observation of four-body ring-exchange interactions and the topological properties of anyonic excitations within an ultracold atom system. A minimum toric code Hamiltonian in which the ring exchange is the dominant term, was implemented by engineering a Hubbard Hamiltonian that describes atomic spins in disconnected plaquette arrays formed by two orthogonal superlattices.