Q 2: Quantum Gases: Bosons 1

Time: Monday 10:30–13:00 Location: HÜL 386

Q 2.1 Mon 10:30 HÜL 386

Two-point density correlations of quasicondensates in free expansion — •Stephanie Manz, Robert Bücker, Thomas Betz, Christian Koller, Igor Mazets, Aurelién Perrin, Thorsten Schumm, and Jörg Schmiedmayer — Atominstitut, TU Wien

We measure the two-point density correlation function of freely expanding quasicondensates in the weakly interacting quasi-one-dimensional (1D) regime. While initially suppressed in the trap, density fluctuations emerge gradually during expansion as a result of initial phase fluctuations present in the trapped quasicondensate. Asymptotically, they are governed by the thermal coherence length of the system. Our measurements take place in an intermediate regime where density correlations are related to near-field diffraction effects and anomalous correlations play an important role. Comparison with a recent theoretical approaches yields good agreement with our experimental results and shows that density correlations can be used for thermometry of quasicondensates. New results testing this method on samples with low atom numbers will be presented as well.

Q 2.2 Mon 10:45 HÜL 386

From Rotating Atomic Rings to Quantum Hall States — Marco Roncaglia[1], •Matteo Rizzi[2], and Jean Dalibard[3] — [1]Dipartimento di Fisica del Politecnico, corso Duca degli Abruzzi 24, I-10129, Torino, Italy — [2]Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Str. 1, D-85748, Garching, Germany — [3]Laboratoire Kastler Brossel, CNRS, UPMC, École normale supe*rieure, 24 rue Lhomond, 75005 Paris, France

Considerable efforts are currently devoted to prepare ultracold neutral atoms in the emblematic strongly correlated quantum Hall regime. The routes followed so far essentially rely on thermodynamics, i.e. imposing the proper Hamiltonian and cooling the system towards its ground state. In rapidly rotating 2D harmonic traps the role of transverse magnetic field is played by the angular velocity. The required huge angular momentum can be obtained only for spinning frequencies extremely near to deconfinement limit; consequently, the prescribed control turns out to be far too stringent.

Here we propose to follow instead a dynamic path starting from the gas confined in a rotating ring by a repulsive "plug" laser. The large moment of inertia of the fluid facilitates the access to states with a large angular momentum, corresponding to a giant vortex. The "plug" is then adiabatically removed, leaving only an harmonic confinement on. We provide clear numerical evidence that for a relatively broad range of initial angular frequencies, the giant vortex state is adiabatically connected to the bosonic $\nu = 1/2$ Laughlin state. We discuss the scaling to many particles and the robustness against trap defects.

Q 2.3 Mon 11:00 HÜL 386

Bose-Einstein condensates in optical micro-potentials — •Johannes Küber, Thomas Lauber, Martin Hasch, Oliver Wille, and Gerhard Birkl — Institut für Angewandte Physik, Technische Universität Darmstadt, Schlossgartenstraße 7, 64289 Darmstadt

Our experiment provides an approach for the coherent manipulation and transport of atoms in optical potentials. We prepare an all-optical Bose-Einstein Condensate (BEC) of 25000 Rb atoms in a crossed optical dipole trap at 1070nm.

Our experiment allows us to create different attractive and repulsive trapping potentials by using miniaturized lenses. Furthermore we can combine these potentials to complex geometries like one dimensional resonators, disk-shaped potentials or toroidal potentials. A one-dimensional optical lattice gives us the ability to control the momentum of atoms loaded into these guiding structures.

In a first set of experiments we demonstrated an interferometer in a one-dimensional waveguide. Therefore we stored the atoms in the waveguide and create a coherent superposition of momentum states with the 1D lattice. In another set of experiments we loaded a BEC in a ring shaped attractive potential and used the ring as a guiding structure for accelerated atoms.

Q 2.4 Mon 11:15 HÜL 386

Bogoliubov theory of disordered Bose-Einstein condensates — •Christopher Gaul[1] and Cord A. Müller[2] — [1]GISC, Departamento de Física de Materiales, Universidad Complutense, E-28040 Madrid, Spain — [2]Centre for Quantum Technologies, National University of Singapore, Singapore 117543, Singapore

We describe repulsively interacting Bose-Einstein condensates in spatially correlated disorder potentials of arbitrary dimension. The first effect of disorder is to deform the mean-field condensate. Secondly, the quantum excitation spectrum and condensate population are affected. By a saddle-point expansion of the many-body Hamiltonian around the deformed mean-field ground state, we find the fundamental quadratic Hamiltonian of quantum fluctuations, in a basis where excitations remain always orthogonal to the deformed condensate. Via Bogoliubov-Nambu perturbation theory, we compute the effective excitation dispersion, including the disorder-corrected sound velocity and localization lengths. Finally, we are able to calculate analytically, for the first time and in all dimensions, the true disorder-induced quantum depletion, i.e. the fraction of particles out of the deformed condensate, which is found to depend strongly on the disorder correlation.

C. Gaul and C.A. Müller, arXiv:1009.5448

Q 2.5 Mon 11:30 HÜL 386

Bose-Einstein condensation of photons in an optical microcavity — •Jan Klärs, Julian Schmitt, Frank Vewinger, and Martin Weitz — Institut für Angewandte Physik, Universität Bonn

Bose-Einstein condensation has been observed in several physical systems, including cold atomic gases and solid-state quasiparticles. However the most omnipresent Bose gas, blackbody radiation, does not show BEC. In such systems the photon number is not conserved when the temperature of the photon gas is varied; at low temperatures, photons disappear in the cavity walls instead of occupying the cavity ground state. A number-conserving thermalization process was experimentally observed for a two-dimensional photon gas in a dye-filled optical microcavity [1]. Here we report the observation of a Bose-Einstein condensate of photons in this system [2]. The cavity mirrors provide both a confining potential and a non-vanishing effective photon mass, making the system formally equivalent to a two-dimensional gas of trapped, massive bosons. The photons thermalize to the temperature of the dye solution (room temperature) by multiple scattering with the dye molecules. Upon increasing the photon density, we observe the following BEC signatures: the photon energies have a Bose-Einstein distribution including a massively populated ground-state mode; the phase transition occurs at the expected photon density and exhibits the predicted dependence on cavity geometry; and the ground-state mode emerges even for a spatially displaced pump spot.

[1] J. Klaers, F. Vewinger and M. Weitz, *Nature Phys.* **6**, 512 (2010)
[2] J. Klaers et al., *Nature* **468**, 545 (2010)

Q 2.6 Mon 11:45 HÜL 386

Quantum phases of polar bosons in ladder-like lattices — •Xiaolong Deng and Luis Santos — ITP, Uni. Hannover, Appelstr. 2, D-30167 Hannover

We study the ground-state properties of polar bosons (e.g. polar bosonic molecules) loaded in ladder-like lattices. By means of DMRG simulations we determine numerically various ground-state correlation functions. We characterize various quantum phases, including pair supersolid, pair superfluid and various Haldane insulator phases for different interaction regimes, and identify the phase diagram for different fillings. Additionally, we also investigate the entanglement spectrum in such a two-lag ladder with 1/2 filling.

Q 2.7 Mon 12:00 HÜL 386

Probing carbon nanotube with cold gases — •Mathias Schneider and Reinhold Walser — Institut für Angewandte Physik, TU Darmstadt

The interaction of carbon nanotubes with cold gases has many unknowns. In particular, the interaction potentials and loss rates are under intense investigations (cf Casimir-Polder potential). In this contribution we would like to ask the inverse question and obtain potential shapes from observed loss rates.

In the case of Bose condensed gases we use superfluid hydrodynamics in a perturbative limit (linear response) to calculate the particle loss rate for certain potential shapes. This model incorporates two basic features. First, the nanotube attracts atoms nearby through a very short ranged attractive potential. Second, inelastic collisions between the nanotube and condensed atoms surrounding it lead to particle loss. Quantities of interest are the density profile of the condensate, the evolution of the ground state occupation number and how these are connected to basic parameters like two body interaction strength, the atom-object collision rate, etc.

Q 2.8 Mon 12:15 HÜL 386

Scaling laws of turbulent ultracold bosons — •Boris Nowak[1,2], Maximilian Schmidt[1,2], Jan Schole[1,2], Denes Sexty[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

Turbulent dynamics in an ultracold Bose gas, in two and three spatial dimensions, is analysed by means of statistical simulations using the classical field equation. A special focus is set on the infrared regime of large-scale excitations following universal power-law distributions distinctly different from those of commonly known weak wave-turbulence phenomena. The infrared power laws which have been predicted within an analytic field-theoretic approach based on the 2PI effective action, are discussed in comparison to the well-known Kolmogorov scaling of vortical motion. These phenomena of strong turbulence should in principle be observable with ultracold atomic gases.

Q 2.9 Mon 12:30 HÜL 386

Transition to quasi-condensation in a low-D Bose gas — •Carsten Henkel[1], Antonio Negretti[2], Stuart P. Cockburn[3], and Nikolaos Proukakis[3] — [1]Universität Potsdam, Germany — [2]Universität Ulm, Germany — [3]Newcastle University, U.K.

We analyze a dilute Bose gas in a one-dimensional trap, using a modified mean field theory based on the Popov approximation [1]. This has been successfully applied to describe density profiles and the border between a quasi-condensate (qc) regime and a non-degenerate gas. We provide simple formulas in an intermediate temperature range for the qc fraction and the total density. A critical chemical potential that delimits the qc and normal phases is identified, and the possibility of a phase transition is explored. We discuss the role of the quantum pressure in a trap and of a renormalized two-body interaction in smoothing out the qc border.

[1] Al Khawaja & al, *Phys. Rev. A* **66** (2002) 013615; Proukakis, *Phys. Rev. A* **74** (2006) 053617

Q 2.10 Mon 12:45 HÜL 386

Numerical simulations on space-time lattices for macroscopic quantum tunneling of Bose-Einstein condensates with attractive 1/r-interaction — •Pascal Wieland, Jörg Main, and Günter Wunner — 1. Institut für Theoretische Physik, Universität Stuttgart

For a special laser-configuration one can induce a self-trapped BEC with an attractive 1/r-interaction which can be described by the Gross-Pitaevskii equation (GPE). Those BECs can collapse due to macroscopic quantum tunneling. The tunneling rate can be calculated with the Euclidean action of the bounce trajectory. We search for the numerical exact bounce trajectory by simulations on a space-time lattice. The time propagation is computed via a split-operator method and the continuity conditions for all time steps are determined using a Newton algorithm.