Q 14: Quantengase: Bosonen 2

Time: Monday 16:30–19:00 Location: V47.02

Q 14.1 Mon 16:30 V47.02

Bose-Einstein condensates in an optical storage ring — •Thomas Lauber[1], Johannes Küber[1], Felix Schmaltz[1], Jordi Mompart[2], and Gerhard Birkl[1] — [1]Institut für Angewandte Physik, Technische Universität Darmstadt, Schlossgartenstraße 7, 64289 Darmstadt — [2]Departament de Física, Universitat Autònoma de Barcelona, E-08193 Bellaterra, Spain

We present the experimental investigation of Bose-Einstein condensates (BEC) in a novel optical storage ring.

The storage ring is based on the application of conical refraction as a new technique for creation of toroidal potentials. An appropriately polished birefringent crystal is used to diffract light to a ring structure of selectable diameter consisting of two concentric bright rings with a dark ring in between. Depending on the detuning with respect to the atomic resonance, conical refraction gives rise to either creating two rings with attractive potential or a potential that gives radial confinement between two repulsive rings. In both cases we use a light sheet for confinement in the dimension perpendicular to the ring plane.

Conical refraction allows numerous possibilities for experimental investigations of a BEC in a potential with periodic boundary conditions. We present results for a BEC that is loaded into a ring with a diameter of $340\,\mu$m and accelerated by means of a Bragg-pulse. We achieve BECs with a mean momentum of 2 or $4\,\hbar k$ and can observe multiple turns in the ring. Conical refracted light is a new approach towards integrated atom-optics and can be easily combined with dipole potentials from micro-optical elements to create more sophisticated configurations.

Q 14.2 Mon 16:45 V47.02

Strongly Interacting One-Dimensional Quantum Gases in optical lattices — •Andreas Vogler, Ralf Labouvie, Felix Stubenrauch, Peter Würtz, Vera Guarrera, and Herwig Ott — Fachbereich Physik, Technische Universität Kaiserslautern

This talk addresses the experimental investigation of the spatial density-profiles of few one-dimensional tubes of ultracold bosons.

In our experiment, we are employing a tightly focussed electron-beam, which ionizes atoms of an atomic cloud by electron-impact ionization. The produced ions are then extracted by means of electrostatic optics and detected. This allows us to probe atomic density distributions with high temporal and spatial resolution. Furthermore, the electron-beam is a versatile tool to manipulate the atomic ensemble. It allows for heating or cooling as well as a reduction of the atom-number. These features are employed to prepare a tailored BEC, which is subsequently loaded into a deep two-dimensional blue-detuned optical lattice. This confines the gas into tens of individual one-dimensional quantum-gases with interaction strengths varying from weak (quasi-condensate) to strong (Tonks-Girardeau). By applying an inverse Abel-Transformation, we are able to extract high-precision density-profiles of effective one-dimensional quantum-gases with different interaction-strengths. These profiles allow for a detailed comparison with theory e.g. the exact zero-temperature Lieb-Liniger model as well as the Yang-Yang model for finite temperatures.

Q 14.3 Mon 17:00 V47.02

Inter-site effects of dipolar interactions in Bose-Einstein condenates in deep optical lattices — Kazimierz Łakomy[1], Rejish Nath[2,3], and •Luis Santos[1] — [1]Institut für Theoretische Physik , Leibniz Universität, Hannover, Appelstrasse 2, D-30167, Hannover, Germany — [2]Max Planck Institute for the Physics of Complex Systems, Nöthnitzer Strasse 38, D-01187 Dresden, Germany — [3]IQOQI and Institute for Theoretical Physics, University of Innsbruck, A-6020 Innsbruck, Austria

Contrary to the non-dipolar case, polar lattice gases are characterized by significant nonlocal inter-site interactions that result in a rich variety of novel physical phenomena. In this talk we show that these inter-site interactions strongly modify the nonlinear physics of a dipolar Bose-Einstein condensate in an optical lattice even in the absence of hopping. First, we report that the destabilization of a dipolar condensate confined in a two-dimensional optical lattice may be followed by correlated modulational instability that evolves spontaneously into soliton filaments or into a checkerboard soliton crystal. Moreover, we will discuss the possibility of forming various types of inter-site soliton molecules (dimers, trimers, etc). Finally we will show how the analysis of Faraday patterns may allow for the experimental study of the collective excitations spectrum shared by non-overlapping sites.

Q 14.4 Mon 17:15 V47.02

Noise induced transport in optical lattices — •Stephan Burkhardt and Sandro Wimberger — Institute for Theoretical Physics, University of Heidelberg

It is well known that condensates in optical lattices undergo Bloch oscillations in the presence of a static force. In addition to these oscillations, tunneling into higher bands can be observed. Our work focuses on how this tunneling can be influenced by noise.

We address the problem of a Bose-Einstein condensate in a tilted bichromatic lattice with added phase noise. For this problem, we present a scaling function that describes the intraband tunneling rates in the regime of weak interactions [1]. From these results we observe that the intraband transport shows a clear maximum for certain noise parameters that can be predicted using the scaling function. Additionally, we characterize the well understood limits of very slow or fast noise which can be compared to reference cases.

Introducing mean-field interactions in the condensate, we finally discuss the interesting case of simultaneous presence of noise and nonlinearity.

[1] G. Tayebirad, R. Mannella, and S. Wimberger, Phys. Rev. A 84, 031605(R) (2011)

Q 14.5 Mon 17:30 V47.02

Non-equilibrium transport in open Bose-Hubbard chains — •Georgios Kordas[1,2], Andreas Komnik[1], Alexandros Karanikas[2], and Sandro Wimberger[1] — [1]Institute for Theoretical Physics, University of Heidelberg, Philosophenweg 19, D-69120 Heidelberg — [2]Nuclear & Particle Physics Section, Physics Department, University of Athens, Panepistimiopolis Ilissia, GR-15771 Athens

We investigate the non-equilibrium transport properties of bosons in an open Bose-Hubbard chain coupled to two bosonic reservoirs. In order to study the dynamics of the system we introduce a Master equation in Lindblad form. We use a mean-field approximation to solve this equation for weakly interacting bosons. For strong interactions in the chain, we go beyond the mean-field description. Finally, we discuss the validity of our approach as compared to other non-equilibrium formalisms.

Q 14.6 Mon 17:45 V47.02

Thermodynamics and Superfluidity of a 2D Bose Gas — Rémi Desbuquois, Lauriane Chomaz, •Christof Weitenberg, Julian Leonard, Tarik Yefsah, Jérôme Beugnon, and Jean Dalibard — Laboratoire Kastler Brossel, CNRS, UPMC, Ecole Normale Supérieure, 24 rue Lhomond, F-75005 Paris, France

Using in situ measurements on a quasi two-dimensional, harmonically trapped 87Rb gas, we infer various equations of state for the equivalent homogeneous fluid. From the dependence of the total atom number and the central density of our clouds with the chemical potential and temperature, we obtain the equations of state for the pressure and the phase-space density. Then using the approximate scale invariance of this two-dimensional system, we determine the entropy per particle. We measure values as low as 0.06 kB in the strongly-degenerate regime, which shows that a 2D Bose gas can constitute an efficient coolant for other quantum fluids.

Moreover, we investigate the superfluidity of the trapped two-dimensional gas. We use a micron-sized laser beam as an obstacle and stir in a circle centered on the gas, thus perturbing at fixed chemical potential. By varying the stirring velocity and monitoring the heating of the system, we can detect the Landau critical velocity, at which dissipation sets it. The critical velocity is limited by the local speed of sound and is therefore a measure for the local superfluid density. By repeating the experiment at different stirring radii we want to explore regions of different local chemical potential and therefore map out the jump of the superfluid density at the BKT transition.

Q 14.7 Mon 18:00 V47.02

Orbital Josephson Effect in driven Bose-Einstein Condensates — •Martin Heimsoth[1,2], Charles Edward Creffield[1], Lincoln Carr[2], and Fernando Sols[1] — [1]Departamento de Física de Materiales, Universidad Complutense de Madrid — [2]Department of Physics, Colorado School of Mines, Golden, Colorado

We analyse the dynamics of Bose-Einstein Condensates (BECs) perturbed by a weak periodic driving field. Our main result is that (under certain conditions) the dynamic of such systems can effectively be described by a time independent few-mode Hamiltonian. This Hamiltonian reveals an analogy of these systems to those which feature the Josephson Effect (JE) in BECs. Hence, we regard this as a new manifestation of the JE in BECs, and term it the Orbital Joesphson Effect. We use our findings to study the rich dynamical behaviour of a hamiltonian quantum ratchet.

Q 14.8 Mon 18:15 V47.02

Josephson oscillations and self-trapping in coupled 1D Bose gases — •Matthias Strauss and Michael Fleischhauer — Fachbereich Physik, Technische Universität Kaiserslautern, D-67663 Kaiserslauternrn

We discuss the dynamics of a pair of tunnel-coupled, trapped one-dimensional Bose gases, where initially all particles are in one of the two traps. The simulation of the time evolution of interacting quantum systems is still a big challenge,and numerically exact methods are often only valid for short times or low particle numbers. For weak interactions and bosonic systems a powerful alternative is the truncated Wigner approximation.On applying this method to the single-particle eigenstates of the harmonic trap, we can simulate the dynamics of 1D gases for long times and high particle numbers (i.e. up to 200) and experimentally realistic interaction strength (gamma $< 1/100$). For large inter-tube tunneling rates we find damped Josephson and quadrupole oscillations and relaxation to a thermal state which we compare to thermal Bethe Ansatz solutions in LDA. We then consider the regime of self-trapping, where in particular the effects of the trap potential are discussed.

Q 14.9 Mon 18:30 V47.02

Dynamics of interacting bosons with tunable exchange symmetry — •Malte C. Tichy, Ole S. Sørensen, Søren Gammelmark, Jacob F. Sherson, and Klaus Mølmer — Lundbeck Foundation Theoretical Center for Quantum System Research, Department of Physics and Astronomy, University of Aarhus, DK-8000 Aarhus, Denmark

Quantum many-body dynamics, such as they are observed in experiments with ultracold atoms, rely on the interparticle interaction as well as on exchange effects induced by the bosonic or fermionic nature of the particles. We present a framework that allows to deliberately tune the strength of both effects in order to achieve a differentiated understanding of the dynamics. For this purpose, the particles are given an additional degree of freedom, which can be realized by coherently populating different hyperfine levels. Within this setting, we study the double-well dynamics of bosons with varying degree of distinguishability. The full counting statistics are extracted via a numerically exact quantum treatment based on the Bose-Hubbard Hamiltonian, which is complemented by a semiclassical description that is rooted in the discrete Gross-Pitaevskii equation. The exchange interaction turns out to be an indispensable ingredient that strongly boosts Josephson-type oscillations.

Q 14.10 Mon 18:45 V47.02

Interference patterns of cat states in ultracold atoms — •Bettina Gertjerenken[1] and Christoph Weiss[1,2] — [1]Institut für Physik, Carl von Ossietzky Universität, D-26111 Oldenburg, Germany — [2]Department of Physics, Durham University, Durham DH1 3LE, United Kingdom

In [1] it has been proposed to create nonlocal quantum superpositions by scattering of bright matter wave solitons at a laser focus. We investigate the interference of the two parts of the quantum superposition and discuss consequences for measurements on the interference pattern.

[1] C. Weiss and Y. Castin, Phys. Rev. Lett. **102**, 010403 (2009)