Q 14: Quantum Gases: Bosons II

Time: Monday 17:00–19:00 Location: P 204

Q 14.1 Mon 17:00 P 204

Bose-Einstein condensates and Conical Refraction: Novel Approach to Toroidal Guiding Potentials for ATOMTRONIC Devices — •Felix Schmaltz, Patrick van Beek, Philip Prediger, Felix Weigand, and Gerhard Birkl — Institut für Angewandte Physik, Technische Universität Darmstadt, Schlossgartenstraße 7, 64289 Darmstadt

We present a novel type of toroidal guiding potential for BEC-based coherent matter waves applicable for atom interferometry or ATOMTRONIC devices such as atomic SQUIDS.

Exploiting the effect of conical refraction in biaxial crystals, we are able to create various types of light field patterns, which can act as dipole force mediated toroidal matter waveguides. Depending on laser beam and crystal parameters, the topology and dimension of these waveguides can be controlled.

Only by changing the waist of the impinging laser beam, the conical refraction light field, using blue detuned light, can be transformed from a harmonical to a toroidal trapping potential. Using dynamically tunable lenses, we can realize the adiabatic transformation of a BEC from a simply connected to a multiply connected trapping topology.

Such a toroidal matter wave can be used to probe superfluidity and vortex-like behavior of confined BECs in a dynamically adjustable fashion.

Q 14.2 Mon 17:15 P 204

Spatially distributed many-particle entanglement in a spinor Bose-Einstein condensate — •Philipp Kunkel, Maximilian Prüfer, Daniel Linnemann, Anika Frölian, Helmut Strobel, Christian-Marcel Schmied, Thomas Gasenzer, and Markus K. Oberthaler — Kirchhoff-Institut für Physik, Im Neuenheimer Feld 227, 69120 Heidelberg

A key resource for distributed quantum-enhanced protocols are entangled states between spatially separated modes. In spinor Bose-Einstein condensates such nonclassical states are routinely generated by short-ranged contact interactions. Here, we use spin mixing in a tightly confined BEC of ^{87}Rb to generate a two-mode squeezed vacuum. Subsequent expansion in a shallow waveguide potential gives rise to nonclassical correlations between opposite spatial directions. Local and global observables are used to quantify the continuous variable entanglement which violates an inequality based on the Einstein-Podolsky-Rosen argument.

Q 14.3 Mon 17:30 P 204

Non-local correlations in interacting bosonic gases - semiclassical results in non-perturbative regimes — •Benjamin Geiger, Quirin Hummel, and Klaus Richter — Institut für Theoretische Physik, Universität Regensburg, Germany

In order to investigate general properties of interacting bosonic gases we present a formalism to calculate thermodynamic properties and the density of states by means of short-time propagation and compare our analytical predictions against quantum integrable models using Bethe ansatz techniques. As an essential input of our approach, we were able to construct the many-body propagator for a one-dimensional free bosonic gas with delta interactions of variable strength. Using this propagator we can give analytical expressions for the smooth part of the many-body density of states as well as spatial two point correlations for the Lieb-Liniger model. We present explicit analytical results for the high-temperature regime which are non-perturbative in the interaction strength and explain numerical observations by Deuar et. al. [1]. Corrections for lower temperatures can be found systematically. A perturbative approach for arbitrary temperatures using Matsubara theory is presented, which is valid in the weakly interacting regime.

[1] P. Deuar et al., Phys. Rev. A 79, 043619 (2009)

Q 14.4 Mon 17:45 P 204

Many-particle quantum dynamics after an interaction quench for ground state quantum bright solitons — •Christoph Weiss[1] and Lincoln Carr[2] — [1]Joint Quantum Centre (JQC) Durham-Newcastle, Department of Physics, Durham University, United Kingdom — [2]Colorado School of Mines, Golden, USA

We investigate attractively interacting bosons in a (quasi-)one-dimensional waveguide initially prepared in the ground state of an additional harmonic potential, a quantum bright soliton. An interaction quench that increases the interaction by a factor of four combined with switching off the potential leads to a higher-order soliton for which the mean-field description via the Gross-Pitaevskii equation predicts oscillations of the variance of the single particle density. By combining numerical investigations using TEBD with analytical Lieb-Liniger results, we show that the soliton breaks apart. This behaviour is visible when measuring the relative distance between particles.

Q 14.5 Mon 18:00 P 204

Understanding quantum phase transitions in the attractive Lieb-Liniger model by quantizing critical mean-field behaviour — •Quirin Hummel, Benjamin Geiger, Juan-Diego Urbina, and Klaus Richter — Institut für Theoretische Physik, Universität Regensburg, Germany

We consider a one-dimensional model of Bosons with attractive interactions which is known to display a quantum phase transition (QPT) at a critical value of the interaction strength α. A semiclassical quantization, where a large number of particles N plays the role of small $\hbar$, allows us to find the parameters of the QPT in terms of quantized orbits passing through a separatrix in classical phase space. Moreover it allows us to analytically quantify effects arising from the discreteness of the quantum mechanical spectrum like the scaling of the ground state gap with N right at the critical α (explaining the numerical findings in [1]), and the high-density spectrum around the excited state QPT for larger couplings. We extract the exact time-scale of the latter - also known as the scrambling time - and rigurously show that it is related to a stability exponent of the underlying classical dynamics. Finally, the universal applicability of our ideas whenever the QPT is related to similar classical behaviour, leads us to expect that this semiclassical picture can be applied to a broad class of QPT with effective one-dimensional descriptions (e.g. Dicke model, Lipkin-Meshkov-Glick model).

[1] R Kanamoto and H Saito and M Ueda, Phys. Rev. A 67, 013608 (2003)

Q 14.6 Mon 18:15 P 204

Signatures of distinguishability in many-body dynamics — •Gabriel Dufour, Tobias Brünner, Maximilian Dirkmann, Alberto Rodriguez, and Andreas Buchleitner — Physikalisches Institut, Albert-Ludwigs-Universität Freiburg

The dynamics of ensembles of quantum particles depends on whether these particles can be distinguished from one another. Indeed, the requirement that many-body states be symmetric under the exchange of identical particles leads to intricate interference effects. These effects have mainly been investigated in the case of non-interacting particles, such as photons in interferometers, but they also play a role in the behaviour of interacting particles, e.g. atoms trapped in optical lattices.

We investigate the ways in which the dynamics of distinguishable and indistinguishable particles differ. To do so, we consider ensembles of bosons condensed into a finite number of modes and which can belong to one of several mutually distinguishable “species”. We study the structure of the corresponding Hilbert space and its consequences for the dynamics. Moreover, we identify a suitable measure of the level of distinguishability in the system. These results are illustrated by a study of the dynamics of a two-component Bose-Einstein condensate in a double-well.

Q 14.7 Mon 18:30 P 204

Properties of quantum filaments in dipolar Bose-Einstein condensates — •Falk Wächtler and Luis Santos — Institut für Theoretische Physik, Leibniz Universität Hannover, Hannover, Germany

Recent experiments with the highly magnetic atoms dysprosium and erbium have revealed the formation of stable quantum droplets in dipolar Bose-Einstein condensates. This surprising result has been explained by the stabilization given by quantum fluctuations. We will discuss properties of a dipolar BEC in the presence of quantum stabilization focusing in particular on the low-lying excitations all the way from the mean-field to the droplet regime. Moreover, we will show the effects of three-body losses for the dynamics of droplet formation as well as the role of quantum fluctuations in the strength of the three-body losses. This shows a large increase of the losses in the droplet regime significantly lowering their lifetime.

Q 14.8 Mon 18:45 P 204

Quantum Domain Walls Induce Incommensurate Supersolid Phase on the Anisotropic Triangular Lattice — Xue-Feng Zhang[1,2,3], Shijie Hu[1], •Axel Pelster[1], and Sebastian Eggert[1] — [1]Physics Department and Research Center OPTIMAS, University of Kaiserslautern, 67663 Kaiserslautern, Germany — [2]Max-Planck-Institute for the Physics of Complex Systems, 01187 Dresden, Germany — [3]State Key Laboratory of Theoretical Physics, Institute of Theoretical Physics, Chinese Academy of Sciences, Beijing 100190, China

We investigate the extended hard-core Bose-Hubbard model on the triangular lattice as a function of spatial anisotropy with respect to both hopping and nearest-neighbor interaction strength [1]. At half-filling the system can be tuned from decoupled one-dimensional chains to a two-dimensional solid phase with alternating density order by adjusting the anisotropic coupling. At intermediate anisotropy, however, frustration effects dominate and an incommensurate supersolid phase emerges, which is characterized by incommensurate density order as well as an anisotropic superfluid density. We demonstrate that this intermediate phase results from the proliferation of topological defects in the form of quantum bosonic domain walls. Accordingly, the structure factor has peaks at wave vectors, which are linearly related to the number of domain walls in a finite system in agreement with extensive quantum Monte Carlo simulations. We discuss possible connections with the supersolid behavior in the high-temperature superconducting striped phase.

[1] Phys. Rev. Lett. **117**, 193201 (2016)