Q 22: Quantengase: Wechselwirkungseffekte 1

Time: Tuesday 10:30–12:30 Location: V7.03

Group Report Q 22.1 Tue 10:30 V7.03

Dipolar Bose-Einstein Condensates with Weak Disorder — •Axel Pelster — Hanse-Wissenschaftskolleg, Delmenhorst, Germany

Recent progress nourishes the prospects of future experiments which investigate Bose-Einstein condensates (BECs) with a strong anisotropic and long-range dipole-dipole interaction. Against this background we solve semiclassicaly the Bogoliubov-de Gennes theory for harmonically trapped dipolar BECs which is justified in the thermodynamic limit [1]. In this way we predict for various static and dynamic observables quantum fluctuations, which go beyond the so far experimentally established mean-field theory.

Furthermore, we report on recent progress in understanding the properties of ultracold bosonic atoms in potentials with quenched disorder [2]. This notoriously difficult *dirty boson problem* is experimentally relevant for the miniaturization of BECs on chips and can also be studied by tailoring disorder potentials via laser speckle fields. Theoretically it is intriguing because of the competition of localization and interaction as well as of disorder and superfluidity.

Finally, we combine both previous topics and consider the impact of weak disorder upon a polarized homogeneous dipolar BEC. We find that both disorder [3] and thermal fluctuations lead to anisotropic superfluidity which can only be described by a corresponding extension of the standard hydrodynamic Landau-Khalatnikov (LK) theory. A linearization of the modified LK equations yields for first and second sound a characteristic direction dependence which should be detectable with Bragg spectroscopy.

[1] A.R.P. Lima and A. Pelster, Phys. Rev. A **84**, 041604(R) (2011) and `arXiv:1111.0900`.
[2] R. Graham and A. Pelster, Int. J. Bif. Chaos **19**, 2745 (2009).
[3] C. Krumnow and A. Pelster, Phys. Rev. A **84**, 021608(R) (2011).

Q 22.2 Tue 11:00 V7.03

Faraday waves in elongated two-component Bose-Einstein condensates — •Antun Balaž[1] and Alexandru Nicolin[2] — [1]Scientific Computing Laboratory, Institute of Physics Belgrade, University of Belgrade, Serbia — [2]Horia Hulubei National Institute for Physics and Nuclear Engineering, Department of Theoretical Physics, Bucharest, Romania

We show by extensive numerical simulations and analytical variational calculations that elongated binary non-miscible Bose-Einstein condensates subject to periodic modulations of the radial confinement exhibit a Faraday instability similar to that seen in one-component condensates. Considering the hyperfine states of ^{87}Rb condensates, we show that there are two experimentally relevant stationary state configurations: the one in which the components form a dark-bright symbiotic pair (the ground state of the system), and the one in which the components are segregated (first excited state). For each of these two configurations, we show numerically that far from resonances the Faraday waves excited in the two components are of similar periods, emerge simultaneously, and do not impact the dynamics of the bulk of the condensate. We derive analytically the period of the Faraday waves using a variational treatment of the coupled Gross-Pitaevskii equations combined with a Mathieu-type analysis for the selection mechanism of the excited waves. Finally, we show that for a modulation frequency close to twice that of the radial trapping, the emergent surface waves fade out in favor of a forceful collective mode that turns the two condensate components miscible.

Q 22.3 Tue 11:15 V7.03

Perturbative calculation of critical exponents for the Bose-Hubbard model — •Dennis Hinrichs[1], Axel Pelster[2], and Martin Holthaus[1] — [1]Institut für Physik, Carl von Ossietzky Universität Oldenburg, 26111 Oldenburg — [2]Hanse-Wissenschaftskolleg, 27753 Delmenhorst

The process-chain approach is a powerful tool for carrying out perturbative calculations for many-body lattice systems in high order of the hopping strength [1]. In combination with the method of the effective potential, this technique permits us to determine characteristic quantities with an accuracy far greater than that of mean-field methods.

In this talk I will concentrate on the calculation of the superfluid and of the condensate density for the Bose-Hubbard model, and demonstrate how the process-chain approach can be employed for obtaining the critical exponents characterizing the system near the superfluid-to-Mott insulator quantum phase transition.

[1] N. Teichmann, D. Hinrichs, M. Holthaus, and A. Eckardt, PRB 79, 224515 (2009).

Q 22.4 Tue 11:30 V7.03

Fractional Quantum Hall Effect of Rydberg-Polaritons — •Fabian Grusdt[1], Michael Fleischhauer[1], Michael Höning[1], and Johannes Otterbach[2] — [1]Fachbereich Physik und Landesforschungszentrum OPTIMAS, TU Kaiserslautern — [2]Physics Department, Harvard University, Cambridge, Massachusetts, USA

Dark-state-polaritons (DSP) are bosonic quasiparticles arising in the interaction of light with 3-level atoms under conditions of electromagnetically induced transparency (EIT). They can be exposed to artificial magnetic fields, strong enough to enter the lowest Landau level regime [Otterbach et. al., Phys. Rev. Lett. 104 (2010)]. We consider additional Van-der-Waals interactions, as realized e.g. when the EIT 3-level atom contains a Rydberg-excited state, and investigate the resulting fractional quantum Hall effect of the DSPs. The realization of the $\nu = 1/2$-Laughlin state and its anyonic quasihole excitations via strong Polariton-Polariton losses is discussed. A numerical and semi-analytical evaluation of the gap to these excitations is presented and the implications for the robustness of such states are shown.

Q 22.5 Tue 11:45 V7.03

Supersolid Vortex Crystals in Rydberg-dressed Bose-Einstein Condensates — •Fabio Cinti[1], Nils Henkel[1], Piyush Jain[2], Guido Pupillo[3,4], and Thomas Pohl[1] — [1]Max Planck Institute for the Physics of Complex Systems, Dresden — [2]University of Alberta, Edmonton, Canada — [3]IQOQI, Innsbruck, Austria. — [4]Universite' de Strasbourg and CNRS, Strasbourg, France.

We investigate quasi-two-dimensional Bose-Einstein-condensates, in which atoms are dressed to a highly excited Rydberg state. In particular, we study the possibility to create and detect supersolid states via probing the response to trap rotations. Combining results of first-principle Quantum Monte Carlo simulations and simplified mean field calculations, we identify universal scaling laws that permit to estimate experimental parameters for supersolid creation over a wide range of temperatures and particle numbers.

For rapid rotation, the mean field results predict an interesting competition between the supersolid crystal structure and the rotation-induced vortex lattice that gives rise to new phases, including arrays of mesoscopic vortex crystals [1].

[1] N. Henkel, F. Cinti, P. Jain, G. Pupillo and T. Pohl, arXiv:1111.5761

Q 22.6 Tue 12:00 V7.03

Transition state theory for wave packet dynamics. Thermal decay of Bose-Einstein condensates with long-range interaction — •Andrej Junginger, Markus Dorwarth, Jörg Main, and Günter Wunner — 1. Institut für Theoretische Physik, Universität Stuttgart

We demonstrate the application of transition state theory to wave packet dynamics in metastable, both linear and nonlinear Schrödinger systems which are approached by means of a variational ansatz for the wave function and whose dynamics is described within the framework of a time-dependent variational principle.

The application of classical transition state theory, which requires knowledge of a classical Hamilton function, is made possible by mapping the variational parameters to classical phase space coordinates and constructing an appropriate Hamiltonian in action variables. This mapping is performed by a normal form expansion of the equations of motion and an additional adaptation to the energy functional.

The applicability of the procedure is demonstrated for Bose-Einstein condensates with long-range interaction using *coupled* Gaussian wave functions. We discuss results obtained for different number of Gaussians and different normal form orders.

Q 22.7 Tue 12:15 V7.03

Macroscopic quantum tunnelling and bounce solutions

of Bose-Einstein condensates with dipolar interactions —
•Torsten Schwidder, Jörg Main, and Günter Wunner — 1. Institut für Theoretische Physik, Universität Stuttgart

Macroscopic quantum tunnelling is discussed for Bose-Einstein condensates with dipolar interaction. The decay of a metastable ground state into a collapsing wave function is investigated in a time-dependent variational approach to the nonlinear Gross-Pitaevskii equation. The bounce trajectory is computed in imaginary time using a multi-shooting algorithm, and tunnelling rates are calculated. The fluctuation prefactor is accessible using the monodromy matrix, and the relation to the Gelfand-Yaglom differential equation is shown.