Q 19: Quantum Gases: Miscellaneous

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

Q 19.1 Tue 10:30 HÜL 386

Interacting ultracold bosons in optical lattices: Scattering and decoherence — •Hannah Venzl[1], Stefan Hunn[1], Scott Sanders[1], Tobias Zech[1], Lewin Stein[1,2], Florian Mintert[3], Moritz Hiller[1], and Andreas Buchleitner[1] — [1]Physikalisches Institut, Albert-Ludwigs-Universität Freiburg, Hermann-Herder-Str. 3, 79104 Freiburg — [2]Technische Universität Berlin, Hardenbergstr. 36, 10623 Berlin — [3]Freiburg Institute for Advanced Studies (FRIAS), Albert-Ludwigs-Universität Freiburg, Albertstraße 19, 79104 Freiburg

Ultracold bosons in optical lattices provide a versatile testing ground to investigate complex quantum phenomena. In this talk, we address the implications of the inter-particle interactions from two complementary perspectives: On the one hand, we devise a matter-wave scattering approach and probe the system via the inelastic scattering cross section. Within the first-order Born approximation, we reveal unambigous traces of the Mott-insulator to superfluid phase transition. Beyond these ground-state properties, also the excitation spectrum of a BEC is probed. In the parameter regime where the interactions induce chaotic spectral statistics, we observe universal Ericson fluctuations with characteristic features rooted in the underlying mean-field equations.

On the other hand, we investigate how the spectral properties are reflected in the system's dynamics: We find that the interactions lead to decoherence, which results in a fast and irreversible decay of Bloch oscillations, and obtain the corresponding decay rate from the local density of states.

Q 19.2 Tue 11:00 HÜL 386

Modulation of polariton condensates with acoustic periodic potentials — •Edgar Cerda[1], Dmitryi Krizhanovskii[2], Klaus Biermann[1], Michiel Wouters[3], Rudolf Hey[1], Paulo Santos[1], and Maurice Skolnick[2] — [1]Paul-Drude-Institut Berlin, Hausvogteiplatz 5-7, 10117 Berlin, Germany — [2]University of Sheffield, Sheffield S3 7RH, United Kingdom — [3]Ecole Polytechnique Fédérale de Lausanne, 1015 Lausanne, Switzerland

Exciton-polaritons are particles formed by the strong coupling between light and excitons in a semiconductor microcavity with embedded quantum wells (QWs). Being composite bosons in the dilute limite with very low mass, they are prone to condensation. In this work, we use surface acoustic waves (SAWs) propagating in a microcavity structure with QWs to create a periodic potential for polaritons by modulating the cavity thickness and the QW energy band gap. The modulation is realised with a SAW of wavelength $\lambda_{SAW} = 8\mu$m propagating along a non-piezoelectric direction ([100]) of a (001)-GaAs microcavity. We investigate the effects of SAWs on the spatial coherence properties of exciton-polariton condensates. By increasing the applied power, the SAW modulation reduces the coherence length L_y in a controlled manner until the extended state is fragmented into weakly interacting wires confined at the valleys of the SAW wavefronts with width equal to $L_y = \lambda_{SAW}/2 = 4\mu$m. The decrease of L_y is understood in terms of the reduction of the tunneling coupling between adjacent wires and in the case of OPO, also by the spatial modulation of the pump.

Q 19.3 Tue 11:15 HÜL 386

Many-Body Effects on the Frustrated Diamond Chain — •Leonardo Mazza and Matteo Rizzi — Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Str. 1, 85748 Garching, Deutschland

We study the Bose-Hubbard model on a quasi-1D periodic structure of rhombi embedded in a homogeneous magnetic field, i.e. the so-called fully-frustrated Diamond Chain. The system is characterized by flat single-particle dispersion relations, i.e. by localization in the absence of disorder. Conversely, interactions tend to induce delocalization effects preserving on-site parity [Douçot and Vidal, Phys.Rev.Lett. 88,227005(2002)]. The phase diagram of the many-body problem is investigated by means of analytical and numerical approaches and it displays unconventional uncompressible phases, Bose glass and pairs quasi-condensate.

Q 19.4 Tue 11:30 HÜL 386

A single fermion in a Bose Josephson Junction — •Maximilian Rinck and Christoph Bruder — Deptartement Physik der Universität Basel, Klingelbergstr. 82, 4056 Basel, Schweiz

We consider the tunneling properties of a single fermionic impurity immersed in a Bose–Einstein condensate in a double-well potential. For strong boson–fermion interaction, we show the existence of a tunnel resonance where a large number of bosons and the fermion tunnel simultaneously. We give analytical expressions for the lineshape of the resonance using degenerate Brillouin–Wigner theory. We finally compute the time-dependent dynamics of the mixture. Using the fermionic tunnel resonances as beam splitter for wave-functions, we construct a Mach–Zehnder interferometer that allows complete population transfer from one well to the other by tilting the double-well potential and only taking into account the fermion's tunnel properties.

Q 19.5 Tue 11:45 HÜL 386

Nonclassical States of Matter generated by Parametric Amplification in a Spinor BEC — •Manuel Scherer[1], Bernd Lücke[1], Jan Peise[1], Jens Kruse[1], Oliver Topic[1], Frank Deuretzbacher[2], Wolfgang Ertmer[1], Luis Santos[2], Jan Arlt[3], and Carsten Klempt[1] — [1]Institut für Quantenoptik, Leibniz Universität Hannover — [2]Institut für Theoretische Physik, Leibniz Universität Hannover — [3]QUANTOP, Department of Physics and Astronomy, University of Aarhus

The two-mode Optical Parametric Amplifier is the standard tool in optics to realize number and phase squeezing in relative observables. We have shown that the spin dynamics in a Bose-Einstein condensate (BEC) with a spin degree of freedom can provide a two-mode parametric amplification of matter waves. At first, we report on the effects of phase sum squeezing on the spontaneous creation of spin patterns. Furthermore, the created matter waves show ultralow fluctuations in the relative atom number. We observe a variance of up to 8 dB below the shot noise limit at a total particle number of more than 10^4 atoms. By coupling the two created clouds via microwave pulses, we construct a beam splitter for these non-classical matter waves. We report on super-Poissonian fluctuations after the beam splitter, in agreement with the large fluctuations of the conjugate variable.

In the future, a second beam splitter will allow for closing the non-classical interferometer with the prospect of a Heisenberg limited sensitivity.

Q 19.6 Tue 12:00 HÜL 386

Process-chain approach applied to the Bose-Hubbard model — •Dennis Hinrichs, Niklas Teichmann, and Martin Holthaus — Institut für Physik, Carl von Ossietzky Universität Oldenburg, 26111 Oldenburg

The process-chain approach is a powerful tool for carrying out perturbative calculations on many-body lattice systems in high order. In combination with the method of the effective potential, this technique permits us to determine the phase boundary marking the superfluid to Mott-insulator quantum phase transition for various lattice types with high accuracy [1]. Moreover, it will be shown that it also gives access to the superfluid density, and to critical exponents.

[1] N. Teichmann, D. Hinrichs, M. Holthaus, EPL 91, 10004 (2010)

Q 19.7 Tue 12:15 HÜL 386

Comparison of stochastic techniques for finite temperature Bose gases — Stuart Cockburn[1], •Antonio Negretti[2], Nikolaos Proukakis[1], and Carsten Henkel[3] — [1]School of Mathematics and Statistics, University of Newcastle upon Tyne, Newcastle upon Tyne, NE1 7RU, United Kingdom — [2]Institut für Quanteninformationsverarbeitung, Universität Ulm, Albert- Einstein-Allee 11, 89069 Ulm, Germany — [3]Institut für Physik und Astronomie, Universität Potsdam, Karl-Liebknecht-Str. 24-25, 14476 Potsdam, Germany

In this talk we analyze two stochastic approaches for describing weakly interacting, trapped quasi-one-dimensional Bose gases at finite temperatures: a number-conserving Bogoliubov (ncB) approach and a stochastic Gross-Pitaevskii equation (sGPe). Density profiles, correlation functions, and the condensate statistics are compared to predictions based upon alternative theories. Although the two stochastic methods are built on different thermodynamic ensembles (ncB: canonical, sGPe:grand-canonical), they yield the correct condensate statistics in a large BEC (strong enough particle interactions). For smaller systems, the sGPe results are prone to anomalously large number fluctuations, well-known for the grand-canonical, ideal Bose gas, whereas the ncB approach, due to thermal phase fluctuations, loses its validity at relatively low temperatures.

Q 19.8 Tue 12:30 HÜL 386

Non-abelian Gauge-field simulators with cold atoms — •Torben Schulze[1], Naceur Gaaloul[1], Holger Ahlers[1], Sebastian Bode[1], Felix Kösel[1], Vyacheslav Lebedev[1], Wolfgang Ertmer[1], Luis Santos[2], and Ernst Rasel[1] — [1]Institut für Quantenoptik, LU Hannover — [2]Institut für Theoretische Physik, LU Hannover

The study of strongly correlated regimes using cold-atom systems is a long-standing challenge for physicists. The charge neutrality of the atoms and the consequent absence of a Lorentz force are strong limitations to this end. The experimental realization of rotating degenerate quantum gases demonstrated the potential of atomic systems to simulate charged particles subject to a uniform magnetic field. However, due to centrifugal forces and technical issues this method turned out to be of limited use. Recently, several proposals showed that preparing coherent superpositions of Zeeman sub-states of atoms which evolve adiabatically in a laser field could drive the matter wave to acquire a Berry phase. This phase translates into a non-vanishing synthetic magnetic field which could be used to engineer a Lorentz force-like for atoms. We present a practical scheme where atomic populations of a degenerate spinor system are driven by appropriate laser arrangements leading to the appearance of gauge field structures. The use of realistic parameters and atomic spectral data make of this method a receipt to implement quantum simulators of gauge fields including the general class of non-abelian (non-commutative) gauges, so far never observed for atoms.

Q 19.9 Tue 12:45 HÜL 386

Strong-field-QED analogue on the lattice — Ralf Schützhold and •Nikodem Szpak — Fakultät für Physik, Universität Duisburg-Essen

We present a model describing cold atoms in an optical lattice which is capable of showing phenomena known from the strong field QED, like the Schwinger effect or adiabatic spontaneous pair creation. This requires re-derivation of an effective Fermi-Hubbard Hamiltonian from first principles. The main advantage of this analogue model is experimental accessibility of the strong field regime in contrast to the real QED.