Q 49: Quantum gases: Lattices I

Time: Thursday 16:30–18:15 Location: UDL HS2002

Q 49.1 Thu 16:30 UDL HS2002

Hierarchy of correlations in the Bose-Hubbard model — •Patrick Navez[1], Konstantin Krutitsky[1], Friedemann Queisser[2], and Ralf Schützhold[1] — [1]Universtät Duisburg-Essen, Lotharstrasse 1, 47057 Duisburg, Germany — [2]The University of British Columbia, 6224 Agricultural Road, Vancouver, BC V6T 1Z1, Canada

We consider the Bose-Hubbard model in the (formal) limit of large coordination numbers Z and derive a hierarchy of correlations via the $1/Z$-expansion. Truncating this expansion, we obtain a set of approximate equations governing the time-dependence of the on-site reduced density matrix and the correlations between two lattice sites (which can be far apart). In some cases, this set of equations can be solved analytically [1,2,3]. In the more general situation, a numerical solution yields the time-dependence of the correlations and provides an alternative to other techniques such as density-renormalization group (or matrix-product state) methods.

Ref: [1] *Emergence of coherence in the Mott-superfluid quench of the Bose-Hubbard model*, P. Navez, R. Schützhold, Phys. Rev. A, **82** 063603 (2010); [2]*Quasi-particle approach for general lattice Hamiltonians*, P. Navez, F. Queisser, R. Schützhold, `arXiv:1303.4112`; [3]*Equilibration versus (pre) thermalization in the Bose and Fermi Hubbard models*, F. Queisser, K. Krutitsky, P. Navez, R. Schützhold, `arXiv:1311.2212`.

Q 49.2 Thu 16:45 UDL HS2002

Expansion dynamics of ultracold Bosons in a one-dimensional optical lattice — •Bodhaditya Santra, Ralf Labouvie, Simon Heun, and Herwig Ott — Research Center OPTIMAS and Fachbereich Physik, Technische Universität Kaiserslautern, 67663 Kaiserslautern, Germany

We experimentally investigate the expansion dynamics of ultracold bosons in a one-dimensional (1D) optical lattice. In our experiment, we prepare a 1D optical lattice with high atom occupancy per lattice site. All the atoms from a central lattice site are removed by a focused electron beam. While the atoms from neighboring sites tunnel into the empty site, the 2D density profiles are measured during the filling-up. We determine the temperature T and the chemical potential μ by fitting the 2D density profile with Hartree-Fock mean-field theory. At the beginning of refilling we observe a higher T and lower μ. As the atom number increases with time, T and μ approaches that of the equilibrium state.

Q 49.3 Thu 17:00 UDL HS2002

Matter-wave scattering from interacting ultracold bosons in optical lattices — •Klaus Mayer, Alberto Rodriguez, and Andreas Buchleitner — Physikalisches Institut, Albert-Ludwigs-Universität Freiburg, Hermann-Herder-Str. 3, 79104 Freiburg

We study matter-wave scattering from ultracold bosons in a one-dimensional optical lattice, described by a Bose-Hubbard Hamiltonian. The phase transition from the superfluid state to the Mott Insulator is clearly displayed in the decay of the inelastic component of the scattering cross-section for increasing onsite interaction U [1]. In order to understand the role of interactions in this process, we perform a Bogoliubov expansion around the condensate and obtain an analytical expression for the cross-section, valid in the regime of small condensate depletion. This allows for the description of the inelastic cross-section's decay in a large range of the relevant system parameters. In the weak-interaction regime, the cross section is found to decay *linearly*, with a slope that is independent of the bosonic density and the system size. To support our analytical results, we present numerical studies obtained from exact diagonalization methods.

[1] S. Sanders, F. Mintert, E. Heller, Phys. Rev. Lett. **105**, 035301 (2010)

Q 49.4 Thu 17:15 UDL HS2002

Dicke super-radiance as a non-destructive probe for the Mott–superfluid phase transition in Bose-Hubbard lattices — •Nicolai ten Brinke and Ralf Schützhold — Fakultät für Physik, Universität Duisburg-Essen, Lotharstraße 1, D-47057 Duisburg, Germany

The behaviour of bosonic atoms in an optical lattice is well described by the Bose-Hubbard model. Depending on the lattice parameters, this model features the quantum phase transition from a Mott-insulator state to a superfluid phase. Typically, this transition is detected by destructive measurements such as time-of-flight experiments or a direct counting of the number (parity) of atoms per lattice site, which destroys their quantum coherence.

We propose and investigate an alternative and less destructive method based on Dicke super-radiance, i.e., the collective and coherent absorption and emission of (infrared) photons by the atom ensemble. In this case, the emitted photons contain information about the coherence properties of the atoms and thus their quantum state. As an example, we study a quantum quench across the Mott–superfluid phase transition and compare it to a (quasi) adiabatic crossover.

Q 49.5 Thu 17:30 UDL HS2002

Bulk Phases and Topological Edge State in the extended 1D Superlattice Bose-Hubbard Model — •Hsiang-Hua Jen, Michael Höning, Fabian Grusdt, and Michael Fleischhauer — Department of Physics, Technische Universität Kaiserslautern, Kaiserslautern, Germany

We investigate ultracold bosonic atoms in a one-dimensional (1D) superlattice with alternating hopping rates, nearest neighbor (NN), and next NN interactions. Motivated by the nontrivial topological edge states in the n=1/2 Mott-insulating (MI) phase [1], we study the quarter filling phase with a fixed ratio of hopping rates (t1/t2) with open boundaries. Depending on the position of the boundary we find localized edge state as well as delocalized single quasihole or quasiparticle states in the bulk. The local excitation at the edge can be melted into the bulk as the hopping increases, and a delocalized quasiparticle emerges.

We use DMRG to analyze the grand canonical phase diagram with sharp boundaries. Within the lobe of the n=1/4 MI phase, a transition from single quasihole to quasiparticle states in the bulk occurs. The existence of this transition is a result of the fractional charge excitations and therefore of nontrivial topology.

[1] F. Grusdt, M. Höning, and M. Fleischhauer, Phys. Rev. Lett. 110, 260405 (2013).

Q 49.6 Thu 17:45 UDL HS2002

Topological transitions of interacting bosons in one-dimensional bi-chromatic optical lattices — •Xiaolong Deng and Luis Santos — ITP, Uni. Hannover

Ultra-cold atoms in 1D bi-chromatic lattices constitute a surprisingly simple system for the study of topological insulators. We show that topological phase transitions constitute a general feature of bosons in 1D bi-chromatic lattices, and that these transitions may occur both as a function of the superlattice strength and due to inter-site interactions. We discuss in addition the topological character of incommensurate density wave phases in quasi-periodic lattices.

Q 49.7 Thu 18:00 UDL HS2002

Interferometric measurement of many-body topological invariants in ultra cold quantum gases — •Fabian Grusdt[1,2], Norman Yao[2], Dmitry Abanin[2,3], and Eugene Demler[2] — [1]Department of physics, research center OPTIMAS and graduate school MAINZ, TU Kaiserslautern — [2]Physics Department, Harvard University — [3]Perimeter Institute, Waterloo, Canada

We present a scheme for the direct detection of many-body topological invariants in ultra cold quantum gases in optical lattices. We generalize single-particle interferometric schemes developed for the detection of topologically non-trivial band structures [Atala et.al., Nature Physics 9, 795 (2013)] by coupling a spin-1/2 impurity to a (topological) excitation of an interacting many-body system. Performing Ramsey interferometry in combination with Bloch oscillations of the resulting composite particle allows to directly detect the many body-topological invariant. In particular we consider adiabatic Thouless pumps, which transport a quantized amount of particles across a one-dimensional lattice. In the presence of inter-atomic interactions this quantized current is given by a many-body Chern number, which can be measured using our protocol. These systems also support symmetry-protected topological phases, the invariants of which can as well be obtained from our protocol.