Q 40: Quantum gases: Optical lattices II

Time: Wednesday 14:00–15:45 Location: A 310

Q 40.1 Wed 14:00 A 310

Expansion dynamics of interacting bosons in homogeneous lattices in one and two dimensions — •Jens Philipp Ronzheimer[1,2], Michael Schreiber[1,2], Simon Braun[1,2], Sean S. Hodgman[1,2], Stephan Langer[2,3], Ian P. McCulloch[4], Fabian Heidrich-Meisner[2,5], Immanuel Bloch[1,2], and Ulrich Schneider[1,2] — [1]LMU München — [2]MPQ Garching — [3]University of Pittsburgh, USA — [4]University of Queensland, Brisbane, Australia — [5]Universität Erlangen-Nürnberg, Erlangen

We study out-of-equilibrium dynamics and transport properties of interacting many-body systems using ultracold atoms in optical lattices. Specifically, we investigate the expansion dynamics of initially localized bosons in homogeneous 1D and 2D Hubbard systems. We find that the fastest, ballistic expansions occur in the integrable limits of the system. In 1D, these are both the non-interacting case as well as the hard-core regime, i.e. the strongly-interacting limits in the absence of doubly or higher occupancies. Any deviation from these limits, either through finite interactions or the admixture of double occupancies in the initial state for strong interactions, significantly slows down the expansion. In 2D, the strongly interacting limit is fundamentally different: Here, the system expands ballistically only in the non-interacting case, while all interactions lead to strongly diffusive behavior. By controlling the tunneling along individual lattice axes, we can gradually change the dimensionality of the system from 1D to 2D. In the strongly interacting case, we observe how the initially ballistic dynamics in a 1D system turn diffusive when additional degrees of freedom become available.

Q 40.2 Wed 14:15 A 310

Mean-field theory for extended Bose-Hubbard model with hard-core bosons — •Mathias May[1], Nicolas Gheeraert[2], Shai Chester[3], Sebastian Eggert[4], and Axel Pelster[4] — [1]Institut für Theoretische Physik, Freie Universität Berlin, Germany — [2]Institute of Theoretical Physics, University of Edinburgh, UK — [3]Physics Department, Columbia University, USA — [4]Fachbereich Physik, Technische Universität Kaiserslautern, Germany

We solve the extended Bose-Hubbard Model with hard-core bosons within mean-field theory for both a quadratic and a triangular lattice. To this end the nearest neighbor terms involving both interaction and hopping are factorized into a mean field and an operator. Assuming additionally a natural division of the lattice into sublattices, we yield a much simpler two- or three-site mean-field Hamiltonian for the quadratic and triangular lattice, respectively. Considering an on-site hard-core interaction allows each site to be occupied by at most one boson, thus the two- or three-site mean-field Hamiltonian reduces to a 4x4- or 8x8-matrix. The resulting energy eigenvalues have to be extremized with respect to the order parameters, which represent the condensate density and the average number of particles for each of the sublattices. As a result we obtain a mean-field phase diagram, which consists of a Mott insulator phase, a density wave phase, a superfluid phase and, for the triangular lattice, also of a supersolid phase. Finally, we determine whether the respective transition lines in the phase diagram are of first or second order and compare our results with recent quantum Monte Carlo simulations.

Q 40.3 Wed 14:30 A 310

Coherent coupling of Bloch bands in an optical lattice — •Christoph Sträter and Andre Eckardt — Max-Planck-Insituitut für Physik komplexer Systeme, 01387 Dresden, Germany

Ultracold quantum gases in optical lattices potentials have gained a lot of attention as a versatile tool for engineering many-body lattice physics under extremely clean and tunable conditions. In the interesting tight-binding regime of deep lattices, where a description in terms of Hubbard-type models applies, the lowest Bloch band is energetically well separated from excited bands. Therefore, orbital degrees of freedom belonging to excited bands are usually frozen out. Methods that have been used experimentally to include orbital freedom are a π-pulse like population transfer to the excited band via Raman coupling [1] and the rapid ramping of superlattice structures [2], both approaches involve considerable heating. Another scheme consists in using the sublattice orbital degree of freedom of special lattice geometries [3]. We are proposing a different method, namely to coherently couple energetically distant bands by employing an external time-periodic force. Such an approach allows to open the orbital freedom adiabatically in different ways under highly tunable conditions. We derive effective time-independent Hubbard models describing the band-coupled system. Within this framework we study the melting of a bosonic Mott-isulator as a result of the coherent band coupling.

[1] T. Müller, S. Fölling, A. Widera, and I. Bloch, PRL 99, 200405 (2007) [2] G. Wirth, M. Ölschläger, and A. Hemmerich, Nature Phys. 7, 147 (2011) [3] P. Soltan-Panahi et al., Nature Phys. 8, 71 (2012)

Q 40.4 Wed 14:45 A 310

Breathing mode in Bose-Hubbard chain with a harmonic trapping potential. — •Wladimir Tschischik, Masud Haque, and Roderich Moessner — Max-Planck-Institut für Physik komplexer Systeme, Dresden

Bosons in the continuum and bosons in optical lattices are both well-studied systems. We investigate the breathing mode of harmonically trapped bosons in the Bose-Hubbard (lattice) model at low fillings, seeking to connect to known results from Gross-Pitaevskii theory for continuum bosons. In 1D systems where there is no true Bose condensation, comparison with Bose-Hubbard dynamics is a particularly stringent test of the Gross-Pitaevskii description, which assumes a condensate. Using several numerical methods, we demonstrate that there is an intermediate interaction regime, between a "free-boson" limit and a "free-fermion" limit, in which the Bose-Hubbard breathing mode frequency approaches the Gross-Pitaevskii prediction.

Q 40.5 Wed 15:00 A 310

An Efficient Approach to Calculating Wannier States and Extension to Inhomogeneous Systems — •Ulf Bissbort and Walter Hofstetter — ITP, Goethe-Universität Frankfurt

Wannier states are a fundamental and central constituent to the construction of many-body models, as they are restricted to the single-particle Hilbert subspace of the respective band, while minimizing the spatial spread. Although simple in their initial definition as discrete Fourier transforms of the Bloch states, their actual computation amounts to a non-trivial high-dimensional minimization problem of the spatial variance as a complex phases of the single-particle Bloch state. Various involved techniques have been devised to efficiently treat this minimization problem, which quickly becomes numerically demanding for all but the simplest lattice geometries. We present an alternative approach, which allows for an efficient numerical calculation of the maximally localized Wannier states and entirely circumvents the pitfalls associated with the minimization technique, such as getting stuck in local minima. The computational effort scales favorably with increasing dimensions and lattice geometries in comparison to the minimization technique. Furthermore it allows for the first clear and unambiguous definition of Wannier states in inhomogeneous systems.

Q 40.6 Wed 15:15 A 310

A new lattice setup for a three-component Fermi gas — •Mathias Neidig, Martin Ries, Andre N. Wenz, Puneet Murthy, Thomas Lompe, and Selim Jochim — Physikalisches Institut, Ruprecht-Karls-Universität Heidelberg

Strongly interacting degenerate three-component Fermi gases are expected to show interesting many-body physics such as the formation of an atomic colour superfluid. However, studying such systems has so far been inhibited by large three-body loss rates. This limitation could be overcome via quantum Zeno loss blocking in a periodic potential. In this talk we present our progress towards realizing a three-component system in a single layer two-dimensional optical lattice.

We have transferred a quantum degenerate two-component gas of ^{6}Li atoms from an optical dipole trap into a stack of pancake shaped potentials with a spacing of about $4\,\mu$m which are formed by the interference pattern of two far off-resonant beams. Using tomographic radio frequency spectroscopy, we can show that we load the atoms into less than five pancakes. In the next step we will optimize this transfer such that we load only one pancake. By adding perpendicular lattice beams and transferring atoms into the third accessible hyperfine state we should then be able to produce a stable, strongly interacting three-component Fermi gas.

Q 40.7 Wed 15:30 A 310

Emergence of coherence in optical lattices — •Simon Braun[1,2], Sean Hodgman[1,2], Michael Schreiber[1,2], Philipp Ronzheimer[1,2], Daniel Garbe[1,2], Immanuel Bloch[1,2], and Ulrich Schneider[1,2] — [1]Ludwig-Maximilians-Universität München — [2]Max-Planck-Institut für Quantenoptik, Garching

Superfluidity in bosonic systems is fundamentally connected with the existence of long-range phase coherence. While this relationship is a well-established concept for equilibrium states also in optical lattices, much less is known about the dynamical emergence of coherence when the superfluid regime is entered. We present a detailed experimental study on how coherence of ultracold bosonic atoms in an optical lattice emerges when crossing the transition from the Mott insulating into the superfluid regime. We analyze the coherence length established in the system in dependence of the transition rate over the phase transition. We find a distinct symmetry between positive and negative temperature states at minimum and maximum kinetic energy, respectively, proving that the dynamics is independent of any residual non-local correlations in the initial Mott insulator. We investigate the behavior in different dimensions and also in an alternative scheme where coherence emerges in a static system after an initial quench.