Q 57: Quantum gases: Lattices II

Time: Friday 10:30–12:30 Location: UDL HS2002

Q 57.1 Fri 10:30 UDL HS2002

Artificial graphene with tunable interactions — •Michael Messer[1], Thomas Uehlinger[1], Gregor Jotzu[1], Daniel Greif[1], Walter Hofstetter[2], Ulf Bissbort[2,3], and Tilman Esslinger[1] — [1]Institute for quantum electronics, ETH Zurich, Zurich, Switzerland — [2]Institut für Theoretische Physik, Goethe Universität Frankfurt, Frankfurt, Germany — [3]Singapore university of technology and design, Singapore

We create an artificial graphene system with tunable interactions and study the crossover from metallic to Mott insulating regimes, both in isolated and coupled two-dimensional honeycomb layers. The artificial graphene consists of a two-component spin mixture of an ultracold atomic Fermi gas loaded into a honeycomb optical lattice. For strong repulsive interactions we observe a suppression of double occupancy and measure a gapped excitation spectrum. We present a quantitative comparison between our measurements and theory, making use of a novel numerical method to obtain Wannier functions for complex lattice structures. Extending our studies to time-resolved measurements, we investigate the equilibration of the double occupancy as a function of lattice loading time.

Q 57.2 Fri 10:45 UDL HS2002

Realization of the Hofstadter Hamiltonian with ultracold atoms in optical lattices — •Michael Lohse[1,2], Monika Aidelsburger[1,2], Marcos Atala[1,2], Julio Barreiro[1,2], Belén Paredes[3], and Immanuel Bloch[1,2] — [1]Fakultät für Physik, Ludwig-Maximilians-Universität, Schellingstrasse 4, 80799 München, Germany — [2]Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Strasse 1, 85748 Garching, Germany — [3]Instituto de Física Teórica CSIC/UAM C /Nicolás Cabrera, 13-15 Cantoblanco, 28049 Madrid, Spain

We developed a new experimental technique to simulate strong uniform artificial magnetic fields on the order of one flux quantum per plaquette with ultracold atoms in optical lattices. Using laser-assisted tunneling in a tilted optical lattice we engineer complex tunneling amplitudes - so called Peierls phases - whose value depends on the position in the lattice. Thereby, atoms hopping in the lattice accumulate a phase shift equivalent to the Aharonov-Bohm phase of charged particles in a magnetic field. We determine the local distribution of fluxes through the observation of cyclotron orbits of the atoms on isolated four-site square plaquettes. Furthermore, we show that for two atomic spin states with opposite magnetic moments, our system naturally realizes the time-reversal-symmetric Hamiltonian underlying the quantum spin Hall effect; i.e., two different spin components experience opposite directions of the magnetic field

Q 57.3 Fri 11:00 UDL HS2002

Dynamical synthetic gauge fields using periodically modulated interactions — Sebastian Greschner[1], •Gaoyong Sun[1], Dario Poletti[2], and Luis Santos[1] — [1]Institut für Theoretische Physik, Leibniz Universität Hannover , Appelstr. 2, DE-30167 Hannover, Germany — [2]Engineering Product Development, Singapore University of Technology and Design, 20 Dover Drive, 138682 Singapore

We show that dynamical synthetic gauge fields may be engineered using periodically modulated interactions. We discuss two scenarios in one-dimensional lattices where periodic interactions may realize a quantum Peierls phase. We discuss how this dynamical gauge field may be probed in stroboscopic measurements of the momentum distribution in time-of-flight experiments. These measurements will show a density-dependent shift of the momentum distribution, revealing as well the quantum character of the created Peierls phase.

Q 57.4 Fri 11:15 UDL HS2002

Superfluid - Mott transition in the presence of artificial gauge fields — •Ivana Vidanovic[1], Alex Petrescu[2], Karyn Le Hur[3], and Walter Hofstetter[1] — [1]Institut für Theoretische Physik, Johann Wolfgang Goethe-Universität, Frankfurt am Main, Germany — [2]Department of Physics, Yale University, New Haven, USA — [3]Centre de Physique Theorique, Ecole Polytechnique, CNRS, Palaiseau Cedex, France

Several recent cold atom experiments reported implementation of artificial gauge fields in optical lattice systems, paving the way toward observation of new phases of matter. Here we study the tight-binding model on the honeycomb lattice introduced by Haldane, for lattice bosons. We analyze the ground state topology and quasiparticle properties in the Mott phase by applying bosonic dynamical mean field theory, strong-coupling perturbation theory and exact diagonalization. The phase diagram also contains two different superfluid phases. The quasiparticle dynamics, number fluctuations, and local currents are measurable in cold atom experiments.

Q 57.5 Fri 11:30 UDL HS2002

Landau-Stark states — •Andrey R. Kolovsky — Kirensky Institute of Physics, 660036 Krasnoyarsk, Russia

The term "Landau-Stark states" refers to eigenstates of a charged particle in a 2D lattice in the presence of normal to the lattice plane magnetic and in-plane electric fields. I shall report the recent progress in understanding unusual properties of the Landau-Stark states [1,2] and discuss application of this newly developed theory to the Hall effect with cold atoms subjected to synthetic electric and magnetic fields [3].

[1] A.R.Kolovsky and G.Mantica, Cyclotron-Bloch dynamics of a quantum particle in a 2D lattice, Phys. Rev. E 83, 041123 (2011); Phys. Rev. E 86, 041146 (2012).

[2] A.R.Kolovsky and G.Mantica, Driven Harper model, Phys. Rev. B 86, 054306 (2012).

[3] A.R.Kolovsky, Master equation approach to conductivity of bosonic and fermionic carriers in one- and two-dimensional lattices, Annalen der Physik, DOI: 10.1002/andp201300169 (2013).

Q 57.6 Fri 11:45 UDL HS2002

Observation of the Meissner effect in bosonic ladders — •Marcos Atala[1,2], Michael Lohse[1,2], Monika Aidelsburger[1,2], Julio Barreiro[1,2], Belén Paredes[3], and Immanuel Bloch[1,2] — [1]Fakultät für Physik, Ludwig-Maximilians-Universität, Schellingstrasse 4, 80799 München, Germany — [2]Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Strasse 1, 85748 Garching, Germany — [3]Instituto de Física Teórica CSIC/UAM C /Nicolás Cabrera, 13-15 Cantoblanco, 28049 Madrid, Spain

We implemented a large uniform effective magnetic field with ultracold atoms using laser-assisted tunneling in a ladder created with an optical lattice. Depending on the ratio between the coupling along the rungs of the ladder and the one along the legs of the ladder, the system presents two different phases: the vortex phase, where the probability currents along the bonds have a vortex structure, and the Meissner phase where the currents form a single vortex of infinite length. In order to detect the probability currents associated to the different phases we populated the ground state of the flux ladder and subsequently projected the state into isolated double well potentials that allowed us to measure the average current direction and strength. We observed the different behavior of the current in both regimes. Furthermore, we also measured the time-of-flight momentum distribution of the ground state for different lattice parameters.

Q 57.7 Fri 12:00 UDL HS2002

String order and correlated phases with periodically modulated interactions — •Sebastian Greschner[1], Luis Santos[1], and Dario Poletti[2] — [1]Institut für Theoretische Physik, Leibniz Universität Hannover, Appelstr. 2, DE-30167 Hannover, Germany — [2]Engineering Product Development, Singapore University of Technology and Design, 20 Dover Drive, 138682 Singapore

The periodic modulation of certain parameters in optical lattice experiments opens interesting possibilities for the control and engineering of lattice gases. Periodically modulated interactions result in a non-linear hopping rate depending on the occupation differences at neighbouring sites [1]. In this way some type of correlated-hopping models [2] as well as dynamical synthetic gauge fields [3] can be engineered. We show how the combined periodic modulation of optical lattices and interactions may be used to realize a very broad class of correlated-hopping Hubbard models for ultracold fermions and bosons. We study the rich physics of this scenario, including pair-superfluidity, dimerized phases as well as exotic Mott-insulator states with a non-vanishing string-order. We also address different aspects of the experimental preparation, stability and detection.

[1] A. Rapp, et al. Phys. Rev. Lett. 109, 203005 (2012).
[2] M. Di Liberto, et al. arXiv:1310.7959 (2013).
[3] S. Greschner, et al. arXiv:1311.3150 (2013).

Q 57.8 Fri 12:15 UDL HS2002

Numerical simulation of the propagation of quantum correlations after a quench in the Bose-Hubbard model — •Konstantin Krutitsky[1], Patrick Navez[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

Using the hierarchy of correlations [1,2,3], we investigate the propagation of quantum correlations after a quench obtained by suddenly switching on the tunneling parameter to the Mott phase in the Bose-Hubbard model in one and two dimensions. To this end, we solve numerically the coupled set of equations for the on-site reduced density matrix and the correlations between two lattice sites. Comparing these results with exact (numerical) diagonalization for small lattices, we find surprisingly good agreement, even in one and two dimensions. For larger lattices, we find that the propagation of quantum correlations obeys an effective light-cone structure and also induces revival properties in ring lattices (with periodic boundary conditions).

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`.