Q 36: Quantum Gases: Bosons IV

Time: Wednesday 14:30–16:15 Location: e001

Q 36.1 Wed 14:30 e001

Generation and Detection of Atomic Spin Entanglement in Optical Lattices — •Han-Ning Dai[1,2,3], Bing Yang[1,2,3], Andreas Reingruber[1,4], Yu-Ao Chen[2,3], Zhen-Sheng Yuan[2,3,1], and Jian-Wei Pan[2,3,1] — [1]Physikalisches Institut, Ruprecht-Karls-Universität Heidelberg, Im Neuenheimer Feld 226, 69120 Heidelberg, Germany — [2]Hefei National Laboratory for Physical Sciences at Microscale and Department of Modern Physics, University of Science and Technology of China, Hefei, Anhui 230026, China — [3]CAS Centre for Excellence and Synergetic Innovation Centre in Quantum Information and Quantum Physics, University of Science and Technology of China, Hefei, Anhui 230026, China — [4]Department of Physics and Research Center OPTIMAS, University of Kaiserslautern, ErwinSchroedinger-Strasse, Building 46, 67663 Kaiserslautern, Germany

We report on the generation, manipulation and detection of atomic spin entanglement in an optical superlattice. Spin entanglement of the two atoms in the double wells of the superlattice is generated via dynamical evolution governed by spin superexchange. By observing collisional atom loss with in-situ absorption imaging we measure spin correlations of atoms inside the double wells and obtain the lower boundary of entanglement fidelity as 0.79±0.06, and the violation of a Bell's inequality with S=2.21±0.08. The above results represent an essential step towards scalable quantum computation with ultracold atoms in optical lattices.

Q 36.2 Wed 14:45 e001

Many body localization of bosons in a two dimensional square lattice — •Jae-yoon Choi[1], Sebastian Hild[1], Johannes Zeiher[1], Antonio Rubio Abadal[1], Immanuel Bloch[1,2], and Christian Gross[1] — [1]Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Straße 1, 85748 Garching, Germany — [2]Fakultät für Physik, Ludwig-Maximilians-Universität München, Schellingstraße 4, 80799 München, Germany

Under which conditions well isolated quantum systems do thermalize is a fundamental question. Many-body localization (MBL) marks a general class of systems which do not thermalize. Microscopic detection of diverging observables near the phase transition remains experimentally challenging, and demonstration of the MBL in higher dimensions is still demanding. We report on recent experiments on many body localization of Bosons in a two dimensional square lattice geometry. We prepare a structured highly excited Mott insulating state which relaxes to a thermal state for vanishing disorder. A projected on-site random disorder potential changes the time evolution significantly and leads to localization. Local observables down to the single atom and single lattice site are used to quantify the temporal changes of the bosonic many body state for different disorder strength.

Q 36.3 Wed 15:00 e001

A Thouless quantum pump with ultracold bosonic atoms in an optical superlattice — •Michael Lohse[1,2], Christian Schweizer[1,2], Oded Zilberberg[3], Monika Aidelsburger[1,2], and Immanuel Bloch[1,2] — [1]Fakultät für Physik, LMU München, Germany — [2]Max-Planck-Institut für Quantenoptik, Garching, Germany — [3]Institut für Theoretische Physik, ETH Zürich, Switzerland

Topological charge pumping enables the transport of charge through an adiabatic cyclic evolution of the underlying Hamiltonian. In contrast to classical transport, the transported charge is quantized and purely determined by the topology of the pump cycle, making it robust to perturbations. Here, we report on the realization of such a pump with ultracold bosonic atoms forming a Mott insulator in a dynamically controlled optical superlattice. By taking in situ images of the cloud,we observe a quantized deflection per pump cycle. We reveal the pump's genuine quantum nature by showing that, in contrast to groundstate particles, a counterintuitive reversed deflection occurs for particles in the first excited band. Furthermore, we directly demonstrate that the system undergoes a controlled topological transition in higher bands when tuning the superlattice parameters. These results open a route to the implementation of more complex pumping schemes, including spin degrees of freedom and higher dimensions.

Q 36.4 Wed 15:15 e001

Reservoir induced topological order and quantized charge pumps in open lattice models with interactions — •Dominik Linzner[1], Malte Koster[1], Fabian Grusdt[2], and Michael Fleischhauer[1] — [1]Fachbereich Physik und Forschungszentrum OPTIMAS, Technische Universität Kaiserslautern, 67663 Kaiserslautern, Deutschland — [2]Department of Physics, Harvard University, Cambridge, Massachusetts 02138, USA

Since the discovery of the quantum Hall effect, topological states of matter have attracted the attention of scientists in many fields of physics. By now there is a rather good understanding of topological order in closed, non-interacting systems. In contrast the extension to open systems in particular with interactions is entirely in its infancy. Recently there have been advances in characterizing topology in reservoir driven systems without interactions [1], but the topological invariants introduced lack a clear physical interpretation and are restricted to non-interacting systems. We consider a one-dimensional interacting topological system whose dynamics is entirely driven by reservoir couplings. By slowly tuning these couplings periodically in time we realize an open-system analogue of the Thouless charge pump [2] that proves to be robust against unitary and non-unitary perturbations. Making use of this Thouless pump we introduce a topological invariant, which has a clear physical meaning and is applicable to interacting systems.

[1]C.E. Bardyn, et al., New J. Phys. 15, 085001 (2013)
[2]D. J. Thouless, Phys. Rev. B 27, 6083 (1983)

Q 36.5 Wed 15:30 e001

Coherent interaction of a Bose-Einstein condensate with two crossed cavity modes — •Julian Leonard, Andrea Morales, Philip Zupancic, Tilman Esslinger, and Tobias Donner — Institute for Quantum Electronics, ETH Zürich, Switzerland

Coupling a quantum gas to the field of a single high-finesse optical cavity gives rise to interactions of infinite range between the atoms, which can create a self-organized state when exceeding a critical strength. It is desirable to tune range and directionality of these interactions, which enables explorations of more complex self-organized states or quantum soft matter physics, such as superfluid glasses and associative memory. However, this requires extending the atom-photon interactions to multiple cavity modes.

We report on the realization of such an extended system, involving a Bose-Einstein condensate coupled to two crossed cavities modes. This already allows to spatially shape the interactions, leading to multiple new crystalline phases, e.g. with hexagonal, triangular or stripe order.

Q 36.6 Wed 15:45 e001

Heating rates of interacting Bosons in shaken optical lattices — •Jakob Näger[1,2], Martin Reitter[1,2], Lucia Duca[1,2], Tracy Li[1,2], Monika Schleier-Smith[4], Immanuel Bloch[1,2], and Ulrich Schneider[3] — [1]Ludwig-Maximilians-Universität München, Schellingstr. 4, 80687 München — [2]Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Strasse 1, 85748 Garching — [3]University of Cambridge, Cambridge, UK — [4]Stanford University, Stanford, CA 94305, Vereinigte Staaten

Periodically driven systems have been successfully used to implement topological band structures with non-zero Chern numbers for non-interacting neutral particles. The extent to which the engineered topological properties survive in the presence of interactions, and which many-body phases result, remains however a largely open question. In order to experimentally control the interactions, and to study the resulting many-body physics, we prepare a BEC of 39K which has an accessible Feshbach resonance. By tuning the interactions as well as the driving strengths and frequencies, we can systematically explore the non-equilibrium dynamics in a shaken 1D lattice as well as in a shaken honeycomb lattice.

Q 36.7 Wed 16:00 e001

Quantum phases emerging from competing short- and long-range interactions in an optical lattice — •Lorenz Hruby, Renate Landig, Nishant Dogra, Manuele Landini, Rafael Mottl, Tobias Donner, and Tilman Esslinger — Quantumoptics group, Institute for Quantum Electronics, ETH Zurich, Switzerland

We experimentally realize a bosonic lattice model with competing short- and infinite-range interactions, and observe the appearance of four distinct phases - a superfluid, a supersolid, a Mott insulator and a charge density wave. Our system is based on a Bose-Einstein condensate trapped in an optical lattice inside a high Finesse optical cavity. The strength of the short-ranged on-site interactions is controlled by means of the optical lattice depth. The infinite-range interaction potential is mediated by a vacuum mode of the cavity and is independently controlled by tuning the cavity resonance. When probing the phase transition between the Mott insulator and the charge density wave in real-time, we discovered a behavior characteristic of a first order phase transition.