Q 72: Ultra-cold Atoms, Ions and BEC V (joint session A/Q)

Time: Friday 11:00–12:45 Location: GrHS Mathe

Q 72.1 Fri 11:00 GrHS Mathe

Interplay of topology and disorder in driven honeycomb lattices — Alexander Hesse[1,2,3], Johannes Arceri[1,2,3], •Moritz Hornung[1,2,3], Christoph Braun[1,2,3], and Monika Aidelsburger[1,2,3] — [1]Ludwig-Maximilians-Universitä Fakultät für Physik, München, Germany — [2]Munich Center for Quantum Science and Technology (MCQST), München, Germany — [3]Max-Planck-Institut für Quantenoptik, Garching, Germany

One of the most fascinating properties of topological phases of matter is their robustness to disorder [1]. While various methods have been developed to probe the geometric properties of Bloch bands with ultracold atoms [2], most fail in the presence of disorder due to their reliance on translational invariance. Here, we demonstrate that topological edge modes can be employed to detect a disorder-induced phase transition between distinct topological phases in a Floquet-engineered 2D optical honeycomb lattice.

[1] J. Zheng, et al., Floquet top. phase transitions, Phys. Rev. B (2024)

[2] N. R. Cooper, J. Dalibard, and I. B. Spielman, Topological bands, Rev. Mod. Phys. (2019)

Q 72.2 Fri 11:15 GrHS Mathe

Cold-atom simulator of a (2+1)D U(1) quantum link model — •Peter Majcen[1,2], Jesse J. Osborne[3], Bing Yang[4], Simone Montangero[1,2], Pietro Silvi[1,2], Philip Hauke[5], and Jad C. Halimeh[6,7] — [1]University of Padua, Italy — [2]INFN Padua, Italy — [3]University of Queensland, Australia — [4]Southern University of Science and Technology, China — [5]University of Trento, Italy — [6]MPI of Quantum Optics, Garching, Germany — [7]LMU, Munich, Germany

The modern description of elementary particles and their interactions is formulated in the language of gauge theories, making them of great interest in theoretical physics. However, first-principle calculations for understanding the emergent phenomena are not always feasible. Possible solutions to this challenge include formulating a Hamiltonian lattice gauge theory and studying it using tensor network techniques or quantum simulators that emulate the dynamics of the theory of interest. A suitable platform for such quantum simulators is ultra-cold atoms. In this work, we adopt a quantum link formulation of QED and present a mapping of a U(1) Quantum Link Model (QLM) for spin S=1 in (2+1)D to a bosonic superlattice. We then propose a scheme for the realization of the target QLM on an extended Bose-Hubbard optical superlattice. Using perturbation theory, we derive an effective description of the QLM and relate its parameters to those of the extended Bose-Hubbard model. To validate the mapping, we show the stability of gauge invariance and the fidelity between the quench dynamics of the extended Bose-Hubbard model and the target QLM, over all accessible evolution times.

Q 72.3 Fri 11:30 GrHS Mathe

Raman sideband imaging of potassium-39 in an optical lattice — •Scott Hubele[1,2], Yixiao Wang[1,2], Martin Schlederer[1,2], Guillaume Salomon[1,2], and Henning Moritz[1,2] — [1]Institute for Quantum Physics, University of Hamburg, Hamburg, Germany — [2]Hamburg Centre for Ultrafast Imaging, University of Hamburg, Hamburg, Germany

Understanding many-body quantum systems, both in and out of equilibrium, is often computationally challenging due to the large Hilbert space of the systems of interest. This makes quantum simulation very attractive, especially when the relevant observables and their correlations can be measured directly. The Bose-Hubbard model for instance, which describes interacting bosons in lattices, can be well simulated using ultracold atoms loaded into optical lattices. High-resolution imaging can then be used to resolve the occupation of each lattice site, in what is known as a quantum gas miscroscope. Here, we present our progress towards building a quantum gas microscope using ultracold potassium-39, to study the Bose-Hubbard model in 2D. We generate a 2D square lattice with a single 1064nm beam in a bowtie geometry and additionally confine the atoms along the vertical direction using a shallow-angle vertical lattice. To readout the system state following some time evolution of the system, we employ Raman sideband cooling at near-zero magnetic field to collect fluorescence on the D1 line. Characterization of our imaging scheme and progress towards single-site resolution is presented.

Q 72.4 Fri 11:45 GrHS Mathe

Floquet realization of large bosonic flux ladders in the strongly correlated regime — •SeungJung Huh[1,2,3], Alexander Impertro[1,2,3], Simon Karch[1,2,3], Irene Rodriguez[1,2,3], Immanuel Bloch[1,2,3], and Monika Aidelsburger[1,2,3] — [1]Fakultät für Physik, Ludwig-Maximilians-Universität, 80799 Munich, Germany — [2]Max-Planck-Institut für Quantenoptik, 85748 Garching, Germany — [3]Munich Center for Quantum Science and Technology (MCQST), 80799 Munich, Germany

In this talk, we will present our results on studying a strongly correlated flux ladder using a neutral atom quantum simulator. After preparing half-filled lattice Cesium atoms with tunable interaction, we experimentally realize the artificial gauge field via laser-assisted tunneling. Measuring local particle currents in a single bond resolution allows us to investigate the ground state phase diagram of interacting Hofstader-Bose Hubbard in a ladder system. We find homogeneous chiral leg current as well as strongly suppressed rung current, a hallmark of Mott-Meissner phase. Finally, we estimate the effective temperature of our system by comparing small system exact diagonalization. This will open avenues to study strongly interacting topological phases such as fractional quantum Hall states.

Q 72.5 Fri 12:00 GrHS Mathe

Probing many-body quantum dynamics using subsystem Loschmidt echos — •Simon Karch[1,2,3], Alexander Impertro[1,2,3], SeungJung Huh[1,2,3], Irene Prieto Rodriguez[1,2,3], Souvik Bandyopadhyay[4], Zheng-Hang Sun[5], Wolfgang Ketterle[6], Markus Heyl[5], Anatoli Polkovnikov[4], Immanuel Bloch[1,2,3], and Monika Aidelsburger[1,2,3] — [1]Fakultät für Physik, LMU, Munich, Germany — [2]Max-Planck-Institut für Quantenoptik, Garching, Germany — [3]MCQST, Munich, Germany — [4]Department of Physics, Boston University, Boston, MA, USA — [5]Institute of Physics, University of Augsburg, Augsburg, Germany — [6]Department of Physics, MIT, Cambridge, MA, USA

The Loschmidt echo - the probability of a quantum many-body system to return to its initial state following a dynamical evolution - is a key quantity in statistical physics. However, it is typically exponentially small, posing significant challenges for experimental measurement. We introduce the subsystem Loschmidt echo, a quasi-local approximation that enables extrapolation to the full-system Loschmidt echo, even in very large systems. Utilizing quantum gas microscopy, we investigate both short- and long-time dynamics of the subsystem Loschmidt echo, demonstrating its ability to capture key features of the Loschmidt echo in a many-body quantum system. In the short-time regime, we use it to observe dynamical quantum phase transitions, while in the long-time regime, our method allows us to measure the inverse participation ratio (IPR), providing a quantitative measure of the dimension of accessible Hilbert space in ergodic and fragmented systems.

Q 72.6 Fri 12:15 GrHS Mathe

Fermionic quantum gates in optical lattices — •Timon Hilker — University of Strathclyde, Glasgow, UK

A fermionic quantum computer uses the occupation of Fermionic modes instead of qubits as the fundamental unit. Such a quantum computer would allow us to run quantum simulations of fermions more efficiently than spin-based quantum computers, which have to map fermionic exchange statistics to qubits via an overhead in resources and circuit depth.

Fermionic atoms in optical lattices have long been used successfully for analog quantum simulations. In this talk, I will discuss how to digitalise the motion and interaction of atoms with gates, and I will indicate how these can extend the current simulations of the Fermi Hubbard model towards hybrid analog-digital simulations, non-local interactions, and applications from material science and quantum chemistry.

Q 72.7 Fri 12:30 GrHS Mathe

Synthetic dimension-induced pseudo Jahn-Teller effect in one-dimensional confined fermions — •André Becker[1,2], Georgios M. Koutentakis[3], and Peter Schmelcher[1,2] — [1]Center for Optical Quantum Technologies, Department of Physics, University of Hamburg, Luruper Chaussee 149, 22761 Hamburg, Germany — [2]The Hamburg Centre for Ultrafast Imaging, University of Hamburg, Luruper Chaussee 149, 22761 Hamburg, Germany — [3]Institute of Science and Technology Austria (ISTA), am Campus 1, 3400 Klosterneuburg, Austria

We demonstrate the failure of the adiabatic Born-Oppenheimer approximation to describe the ground state of a quantum impurity within an ultracold Fermi gas despite substantial mass differences between the bath and impurity species. Increasing repulsion leads to the appearance of nonadiabatic couplings between the fast bath and slow impurity degrees of freedom, which reduce the parity symmetry of the latter according to the pseudo Jahn-Teller effect. The presence of this mechanism is associated to a conical intersection involving the impurity position and the inverse of the interaction strength, which acts as a synthetic dimension. We elucidate the presence of these effects via a detailed ground-state analysis involving the comparison of ab initio fully correlated simulations with effective models. Our study suggests ultracold atomic ensembles as potent emulators of complex molecular phenomena.