Q 12: Quantum Gases (Bosons and Fermions) I

Time: Monday 14:00–15:45 Location: S HS 037 Informatik

Q 12.1 Mon 14:00 S HS 037 Informatik

Measuring quantized circular dichroism in ultracold topological matter — •Luca Asteria[1], Duc Thanh Tran[2], Tomoki Ozawa[3], Matthias Tarnowski[1,4], Benno S. Rem[1,4], Nick Fläschner[1,4], Klaus Sengstock[1,4,5], Nathan Goldman[2], and Christof Weitenberg[1,4] — [1]Institut für Laserphysik, Universität Hamburg, Germany — [2]Center for Nonlinear Phenomena and Complex Systems,Université Libre de Bruxelles, Brussels, Belgium — [3]Interdisciplinary Theoretical and Mathematical Sciences Program (iTHEMS), RIKEN, Wako, Saitama 351-0198, Japan — [4]The Hamburg Centre for Ultrafast Imaging, 22761 Hamburg, Germany — [5]Zentrum für Optische Quantentechnologien, Universität Hamburg, 22761 Hamburg, Germany

The topology of two-dimensional materials traditionally manifests itself through the quantization of the Hall conductance, which is revealed in transport measurements.

Recently, it was predicted that topology can also give rise to a quantized spectroscopic response upon subjecting a Chern insulator to a circular drive.

Here we experimentally demonstrate this intriguing topological effect for the first time, using ultracold fermionic atoms in topological Floquet bands.

In addition, our depletion-rate measurements also provide a first experimental estimation of the Wannier-spread functional, a fundamental geometric property of Bloch bands.

Q 12.2 Mon 14:15 S HS 037 Informatik

Floquet dynamics in driven Fermi-Hubbard systems — •Joaquín Minguzzi, Michael Messer, Kilian Sandholzer, Frederik Görg, Konrad Viebahn, Rémi Desbuquois, and Tilman Esslinger — Institute for Quantum Electronics, ETH Zurich, CH-8093 Zurich

Floquet engineering is a widely applicable method to realize novel effectively static Hamiltonians via driving a quantum system. Several experiments have successfully demonstrated Floquet Hamiltonians in non-interacting ultracold atoms. Yet, the time scales were this effective Hamiltonian is appropiate to describe the dynamics of a driven strongly-interacting many-body state have not been explored. In particular, the system is expected to heat up due to continuous energy absorption from the drive. We experimentally study these aspects in the driven Fermi-Hubbard model using strongly-interacting ultracold fermions in a driven three-dimensional optical lattice. The dynamics of the engineered Floquet state is compared to the one of an equivalent static many-body state. Our observables show that these dynamics coincide up to several hundreds of driving cycles, validating the applicability of the Floquet Hamiltonian. This time scale is ultimately limited by Floquet heating and consequently atom loss, which is mitigated in a lattice with hexagonal geometry. Large bandgaps and less dispersive bands broaden the frequency window suitable for driving with suppresed atom loss. Our results establish that the driven Fermi-Hubbard model can be implemented on realistic experimental time scales and in future work could be benchmarked with theoretical methods.

Q 12.3 Mon 14:30 S HS 037 Informatik

Measuring the topological phase transition via the single-particle density matrix — •Jun-Hui Zheng[1], Bernhard Irsigler[1], Lijia Jiang[2], Christof Weitenberg[3,4], and Walter Hofstetter[1] — [1]Institut für Theoretische Physik, Goethe-Universität, 60438 Frankfurt am Main, Germany — [2]Frankfurt Institute for Advanced Studies, 60438 Frankfurt am Main, Germany — [3]Institut für Laserphysik, Universität Hamburg, Luruper Chaussee 149, 22761 Hamburg, Germany — [4]Hamburg Centre for Ultrafast Imaging, Luruper Chaussee 149, 22761 Hamburg, Germany

We discuss the topological phase transition of the experimentally realizable spin-1/2 fermionic Haldane model with repulsive on-site interaction. We show that the Berry curvature of the topological Hamiltonian, the first Chern number, and the topological phase transition point can be extracted from the single-particle density matrix for this interacting system. Furthermore, we design a scheme for tomography of the single-particle density matrix of interacting fermions in two-dimensional optical lattices with a two-sublattice structure in cold atom experiments.

Q 12.4 Mon 14:45 S HS 037 Informatik

Multipartite entanglement certification in quantum many body systems using quench dynamics — •Ricardo Costa de Almeida[1,2] and Philipp Hauke[1,2] — [1]Kirchhoff-Institut für Physik, INF 227, 69120 Heidelberg, Germany — [2]Institut für Theoretische Physik, Philosophenweg 16, 69120 Heidelberg, Germany

Entanglement detection is a central problem for current experiments exploring quantum many-body physics. Though entanglement witnesses provide a framework to handle this task, their direct use is often problematic due to practical considerations. We overcome such limitations for the quantum Fisher information(QFI), a witness for multipartite entanglement, by introducing a protocol to measure it using quench experiments. In particular, the QFI of thermal states becomes accessible via measurements of the response to quenches in the linear regime. To showcase this technique, we apply it to the one-dimensional Fermi-Hubbard model and calculate the QFI across the phase diagram. We introduce QFI bounds adapted to fermionic systems as previous connections between QFI and multipartite entanglement focused on a bosonic or spin description. As such this allow us to certify the presence of multipartite entanglement in different regions of the phase diagram. We assess the sensitivity of multipartite entanglement to thermal effects and compare the performance of different observables. Our protocol paves the way to experimentally accessing multipartite entanglement that can provide quantum enhancement for metrological devices.

Q 12.5 Mon 15:00 S HS 037 Informatik

Identifying Quantum Phase Transitions using Artificial Neural Networks on Experimental Data — Benno Rem[1,2], •Niklas Käming[1], Matthias Tarnowski[1,2], Luca Asteria[1], Nick Fläschner[1], Christoph Becker[1,3], Klaus Sengstock[1,2,3], and Christof Weitenberg[1,2] — [1]ILP - Institut für Laserphysik, Universität Hamburg, Luruper Chaussee 149, 22761 Hamburg, Germany — [2]The Hamburg Centre for Ultrafast Imaging, Luruper Chaussee 149, 22761 Hamburg, Germany — [3]ZOQ - Zentrum für Optische Quantentechnologien, Universität Hambur g, Luruper Chaussee 149, 22761 Hamburg, Germany

Machine learning techniques such as artificial neural networks are currently revolutionizing many technological areas and have also proven successful in quantum physics applications. Here we employ an artificial neural network and deep learning techniques to identify quantum phase transitions from single-shot experimental momentum-space density images of ultracold quantum gases and obtain results, which were not feasible with conventional methods. We map out the complete two-dimensional topological phase diagram of the Haldane model and provide an accurate characterization of the superfluid-to-Mott-insulator transition in an inhomogeneous Bose-Hubbard system. Our work points the way to unravel complex phase diagrams of general experimental systems, where the Hamiltonian and the order parameters might not be known.

Q 12.6 Mon 15:15 S HS 037 Informatik

A study of the periodically driven, strongly correlated Fermi-Hubbard model using fermions in optical lattices and nonequilibrium DMFT — •Kilian Sandholzer[1], Yuta Murakami[2], Frederik Görg[1], Joaquín Minguzzi[1], Michael Messer[1], Rémi Desbuquois[1], Martin Eckstein[3], Philipp Werner[2], and Tilman Esslinger[1] — [1]ETH Zürich, Switzerland — [2]University of Fribourg, Switzerland — [3]University of Erlangen-Nürnberg, Germany

In condensed matter physics, essential effects of electronic correlations are captured by the Fermi-Hubbard model, which has been extensively studied using quantum simulation and powerful numerical techniques. By introducing a periodic driving force, a broad range of intriguing effects arise, such as dynamical localization or enhancement of antiferromagnetic correlations. The nonequilibrium nature of these effects pushes quantum simulators and numerical methods to their limits. We study the dynamics of double occupations in a driven 3D Fermi-Hubbard model and compare nonequilibrium dynamical mean field theory (DMFT) calculations to experiments with fermions in optical lattices. In the high-frequency regime, we validate the effective static Hamiltonian description and its breakdown at low frequencies. We

further investigate the effect of the modulation amplitude and the detuning in the case where the driving frequency is close to the interaction energy. A good agreement between theory and experiment is found and establishes these methods as versatile tools for studying driving-induced effects in strongly correlated lattice systems.

Q 12.7 Mon 15:30 S HS 037 Informatik

Dimensional phase transitions from 1D quantum liquids to 3D condensates — Polina Matveeva[1], Imke Schneider[1], Sebastian Eggert[1], •Axel Pelster[1], Denis Morath[1], and Dominik Strassel[1,2] — [1]Physics Department and Research Center OPTIMAS, Technische Universität Kaiserslautern, Erwin-Schrödinger Straße 46, 67663 Kaiserslautern, Germany — [2]Competence Center for High Performance Computing, Fraunhofer ITWM, Kaiserslautern, Germany

We consider weakly coupled strongly interacting quantum chains, such as quantum wires, anisotropic ultracold gases, or quasi-1D spin-chain compounds. It is known that a phase transition from the 1D Luttinger liquid behavior to a 3D ordered states can be qualitatively descibed by a chain mean field theory to determine the critical temperature, but the quantitative corrections and the range of validity is not well established. We therefore simulate the transition using a fully 3D microscopic model with very large scale quantum Monte Carlo calculations and compare with theoretical prediction including higher order terms in the chain mean field theory. We not only determine the very strong quantitative corrections, but also find a new regime of low density behavior where long range quantum correlations between the chains dominate the behavior, which leads qualitatively different powerlaws as a function of interchain couplings.