Q 35: Quantum Gases (Fermions) II

Time: Tuesday 14:00–16:15 Location: K 1.022

Q 35.1 Tue 14:00 K 1.022

Artificial gauge potentials in periodically driven optical lattices: numerical simulations of atomic transport — •Ana Hudomal[1], Ivana Vasić[1], Hrvoje Buljan[2], Walter Hofstetter[3], and Antun Balaž[1] — [1]Scientific Computing Laboratory, Center for the Study of Complex Systems, Institute of Physics Belgrade, University of Belgrade, Serbia — [2]Department of Physics, University of Zagreb, Croatia — [3]Institut für Theoretische Physik, Johann Wolfgang Goethe-Universität, Frankfurt am Main, Germany

Artificial gauge potentials have been recently realized in cold-atom experiments with periodically driven optical lattices [1,2]. In such systems, atoms subjected to a constant external force gain an anomalous velocity in the direction transverse to the direction of the applied force. Taking into consideration realistic experimental conditions, we perform numerical simulations in order to investigate the dynamics of atomic clouds and relate it to the Chern number of the effective model. We use the full time-dependent Hamiltonian and take into account the effects of weak repulsive interactions between atoms. The results are compared to the semiclassical approximation.

[1] G. Jotzu et al., Nature **515**, 237 (2014).
[2] M. Aidelsburger et al., Nature Phys. **11**, 162 (2015).

Q 35.2 Tue 14:15 K 1.022

Experimental characterization and control of Floquet states in a periodically driven two-body quantum system — •Kilian Sandholzer, Rémi Desbuquois, Michael Messer, Frederik Görg, Joaquín Minguzzi, Gregor Jotzu, and Tilman Esslinger — Institute for Quantum Electronics, ETH Zürich, Zürich, Switzerland

Floquet engineering is a powerful tool to modify properties of a static system such as opening topological gaps or controlling magnetic order. The versatility of cold atom experiments offers the possibility to implement many of these schemes. Nonetheless, preparing a certain Floquet state that has the desired properties in this out-of-equilibrium situation is a more difficult task, especially when the driving frequency is close to a characteristic energy scale of the system. In this work, we prepare fermionic atoms in a driven optical lattice such that the system can be described by two interacting particles on a double well potential with a periodically modulated tilt. In the case of near-resonant driving we achieve to enter adiabatically individual Floquet states by using a two-step ramping protocol. In addition, the fast coherent dynamics inherently connected to the drive are studied in detail. Finally, an analytical derivation of the effective time-independent Hamiltonian of the realized system is presented and then compared to numerical studies and experimental data.

Q 35.3 Tue 14:30 K 1.022

Dynamics of driven interacting many-body systems — •Michael Messer, Frederik Görg, Kilian Sandholzer, Joaquín Minguzzi, Rémi Desbuquois, and Tilman Esslinger — Institute for Quantum Electronics, ETH Zurich, 8093 Zurich, Switzerland

Periodic driving can be used to coherently control the properties of a many-body state and to engineer new phases which are not accessible in static systems. The successful implementation of a periodically driven Fermi-Hubbard model on a 3D hexagonal lattice offers the possibility to explore the intriguing dynamics of Floquet many-body systems. A theoretical analysis of driven many-body Hamiltonians is inherently challenging, however, in combination with our experiments a deeper understanding seems feasible.

By controlling the detuning between shaking frequency and interactions, and setting a variable strength of the periodic drive, we achieve independent control over the single particle tunneling and the magnetic exchange energy. This control allows us to investigate the dynamics and build-up of nearest-neighbor spin-spin correlations. Furthermore, we explore possible mechanisms behind the formation of correlations in interacting Floquet systems. In addition, we can analyze the creation of double occupancies, as one mechanism to form excitations.

Q 35.4 Tue 14:45 K 1.022

Enhancement and sign change of magnetic correlations in a driven quantum many-body system — •Frederik Görg[1], Michael Messer[1], Kilian Sandholzer[1], Joaquín Minguzzi[1], Gregor Jotzu[1,2], Rémi Desbuquois[1], and Tilman Esslinger[1] — [1]Institute for Quantum Electronics, ETH Zurich, 8093 Zurich, Switzerland — [2]Max Planck Institute for the Structure and Dynamics of Matter, 22761 Hamburg, Germany

Strong periodic driving can be used to control the properties of interacting quantum systems. In solid state experiments, ultrashort laser pulses are employed to tune the charge order as well as magnetic and superconducting properties of materials. At the same time, continuous driving has been used in cold atom experiments to engineer novel effective Floquet-Hamiltonians which feature for example a topological bandstructure. We realize a strongly interacting Fermi gas in a periodically driven hexagonal optical lattice and investigate its charge and magnetic properties. We first demonstrate that in the high-frequency regime, the effective description of the many-body system by a renormalized tunnelling amplitude remains valid by comparing our results to an equivalent static system. When driving at a frequency close to the interaction energy, we show that anti-ferromagnetic correlations can be enhanced or even switched to ferromagnetic ordering. Our observations can be explained by a microscopic model, in which the particle tunnelling and magnetic exchange energies can be controlled independently. Therefore, Floquet engineering constitutes an alternative route to experimentally investigate unconventional pairing.

Q 35.5 Tue 15:00 K 1.022

Manipulating and probing excitations of a Chern insulator by Floquet engineering an optical solenoid — •Botao Wang, Nur Ünal, and André Eckardt — Max Planck Institute for the Physics of Complex Systems, Dresden, Germany

The realization of artificial gauge fields in optical lattice systems has paved a way to the experimental investigation of various topological quantum effects. Here we propose a realistic scheme for realizing tunable local (solenoid type) artificial magnetic fields by means of Floquet engineering. We show that such an optical solenoid field can be used to coherently manipulate and probe Chern insulator states of the Hofstadter Hamiltonian. In particular, we investigate the possibility to create local quasiparticle and quasihole excitations, to coherently populated edge modes, and to achieve quantized charge pumping. All these effects are manifested on the spatial density distributions, which can be measured directly in quantum-gas microscopes.

Q 35.6 Tue 15:15 K 1.022

Characterizing topology by dynamics: Chern number from linking number — •Matthias Tarnowski[1,2], Nur Ünal[3], Nick Fläschner[1,2], Benno Rem[1,2], André Eckardt[3], Klaus Sengstock[1,2,4], and Christof Weitenberg[1,2] — [1]Institut für Laserphysik, Universität Hamburg, 22761 Hamburg, Germany — [2]The Hamburg Centre for Ultrafast Imaging, 22761 Hamburg, Germany — [3]Max-Planck-Institut für Physik komplexer Systeme, Nöthnitzer Straße 38, 01187 Dresden, Germany — [4]Zentrum für Optische Quantentechnologien, Universität Hamburg, 22761 Hamburg, Germany

Topology plays an important role in modern solid state physics describing intriguing quantum states such as topological insulators. It is an intrinsically non-local property and therefore challenging to access, often studied only via the resulting edge states. Here, we report on a new approach by connecting the Chern number with the dynamical evolution of highly excited states of the system and demonstrate it experimentally with cold atoms in hexagonal optical lattices. We study the contour of dynamically created vortex pairs in momentum space following a sudden quench into the system of interest and infer the Chern number of the post-quench Hamiltonian from the topology of the contour, quantified by the linking number with the static vortices. Our work exploits a direct mapping between two topological indices and allows detecting topology by the naked eye.

Q 35.7 Tue 15:30 K 1.022

1D fermionic Floquet topological insulators with Hubbard interaction — •Haixin Qiu[1] and Johann Kroha[1,2] — [1]Physikalisches Institut and Bethe Center for Theoretical Physics, Universität Bonn, Nussallee 12, 53115 Bonn, Germany — [2]Center for Correlated Matter, Zhejiang University, Hangzhou, Zhejiang 310058, China

The fermionic Rice-Mele model is a standard model for quantum ratchet transport in periodically driven, one-dimensional, bipartite chains. In the adiabatic limit, this model exhibits quantized transport (Thouless pump), while in the limit of fast drive quasistatic approximations with effective hopping parameters are possible. Here we study the Rice-Mele model with periodic drive of both, the hopping amplitudes and the onsite energy modulation,in the intermediate regime where the driving frequency is comparable to intrinsic energy scales. In this regime, topological Floquet-Bloch bands are possible because of an effectively two-dimensional Brillouin zone comprised of the periodic k-space and the periodic, continuous time space. We investigate the stability of the topological phase with respect to inelastic interactions. To that end, we include a Hubbard onsite repulsion U in the Floquet Hamiltonian of the Rice-Mele model. The Floquet space is truncated with up to ± 5 Floquet bands. We develop the Keldysh-Floquet Green's function method for stationary non-equilibrium, which is non-trivial already in the non-interacting case because of the bipartite lattice structure. The Hubbard interaction is treated by 2nd-order selfconsistent perturbation theory in U. We present results for the Floquet spectral densities and the transport current.

Q 35.8 Tue 15:45 K 1.022

Strong field QED effect of spontaneous pair creation from vacuum simulated in a 2D optical lattice — Leonhard Klar, •Nikodem Szpak, and Ralf Schützhold — Faculty of Physics, University of Duisburg-Essen, Germany

QED predicts the decay of quantum vacuum and spontaneous creation of electron–positron pairs for sufficiently strong electric fields which, however, could not be reached in any laboratory so far. A promissing alternative, opening this fascinating field to experiments, is offered by optical lattice based quantum simulators [1,2] in which ultra-cold atoms behave in an analogue way to electrons and positrons in QED. We propose a two-dimensional optical lattice setup filled with cold fermions in which excitations of the ground state behave as particles and antiparticles (holes) and satisfy the relativistic Dirac equation. We calculate the pair production rates for slowly varying time-dependent external fields and show that vacuum destabilization occurs only for supercritical fields as predicted by QED [3].

[1] N. Szpak and R. Schützhold, Phys. Rev. A 84, 050101(R) (2011).
[2] N. Szpak and R. Schützhold, New J. Phys. 14 (2012) 035001.
[3] N. Szpak, J. Phys. A: Math. Theor. 41 (2008) 164059 (7pp).

Q 35.9 Tue 16:00 K 1.022

Versatile detection scheme for topological Bloch-state defects — •Marlon Nuske[1], Matthias Tarnowski[2,3], Nick Fläschner[2,3], Benno Rem[2,3], Dominik Vogel[2], Klaus Sengstock[1,2,3], Ludwig Mathey[1,2,3], and Christof Weitenberg[2,3] — [1]Zentrum für optische Quantentechnologien, Universität Hamburg, 22761 Hamburg, Germany — [2]Institut für Laserphysik, Universität Hamburg, 22761 Hamburg, Germany — [3]The Hamburg Centre for Ultrafast Imaging, 22761 Hamburg, Germany

The dynamics in solid state systems is not only governed by the band structure but also by topological defects of the Eigenstates. A paradigmatic example are the Dirac points in graphene. For this system with a two-atomic basis the linear dispersion relation at the Dirac points is accompanied by a vortex of the azimuthal phase of the Eigenstates. In a time-of-flight (ToF) expansion the Eigenstates interfere and the resulting signal contains information about the azimuthal phase. We present a versatile detection scheme that uses off-resonant lattice modulation to extract the azimuthal phase from the ToF signal. This detection scheme is applicable to a variety of two-band systems and can be extended to general multi-band systems.