TT 36: Topological Insulators

Time: Wednesday 15:00–17:45 Location: HSZ 103

TT 36.1 Wed 15:00 HSZ 103

In-plane magnetic field induced asymmetric magnetoconductance in topological insulator kinks — •Gerrit Behner[1,2], Abdur Rehman Jalil[1,2], Kristof Moors[1,2], Erik Zimmermann[1,2], Peter Schüffelgen[1,2], Detlev Grützmacher[1,2], and Thomas Schäpers[1,2] — [1]Peter Grünberg Institut (PGI-9), Forschungszentrum Jülich, 52425 Jülich, Germany — [2]JARA-Fundamentals of Future Information Technology, Jülich-Aachen Research Alliance, Forschungszentrum Jülich and RWTH Aachen University, Germany

The study of the transport properties of quasi one-dimensional topological insulator (TI) nanostructures under the application of an in-plane magnetic field is crucial for the later realization of topological quantum computation building blocks. We present low temperature measurements of selectively grown TI-kinks under the application of an in-plane magnetic field. A dependence of the TI-kink resistance on the the in-plane magnetic field angle is visible in the magneto-transport data resulting in a π-periodic change of the conductance. This phenomenon originates from an orbital effect, leading to a periodic alignment of the phase-coherent states on the bottom and top surface of the topological insulator. Respectively, once the states are aligned an increased conductance in the device is observed. The measurement results are supported theoretically by an analysis of a surface Rashba-Dirac model and tight-binding calculations of an effective three-dimensional model.

TT 36.2 Wed 15:15 HSZ 103

Topological quantum chemistry with a twist — •Axel Fünfhaus, Marius Möller, and Roser Valentí — Goethe Uni Frankfurt, Frankfurt am Main, Germany

It is well known that many topological phases can be indicated by the symmetry behavior of their band structure at high symmetry points, which culminated in the development of topological quantum chemistry. This approach becomes problematic once interactions are added, as this does not permit conserved particle occupation numbers in reciprocal space. We face this challenge by generalizing the Brillouin zone for translation invariant many-body wave functions via a torus of twisted boundary conditions. This allows for a symmetry analysis of the ground state wave function in twisted boundary space. We apply this ansatz to detect topological phases in interacting Chern insulators and fractional Chern insulators as well as Mott insulating systems that cannot adiabatically be connected to atomic limits.

TT 36.3 Wed 15:30 HSZ 103

Phonon-induced breakdown of Thouless pumping in the Rice-Mele-Holstein model — •Suman Mondal, Eric Bertok, and Fabian Heidrich-Meisner — Institut für Theoretische Physik, Georg-August-Universität Göttingen, D-37077 Göttingen, Germany

Adiabatic and periodic variations of the lattice parameters can make it possible to transport charge through a system even without net external electric or magnetic fields, known as Thouless charge pumping. The amount of charge pumped in a cycle is quantized and entirely determined by the system's topology, which is robust against perturbations such as disorder and interactions. However, coupling to the environment may play a vital role in topological transport in many-body systems. In this talk, we will discuss the topological Thouless pumping, where the charge carriers interact with local optical phonons. The semi-classical multi-trajectory Ehrenfest method is employed to treat the phonon trajectories classically and charge carriers quantum mechanically. We find a breakdown of the quantized charge transport in the presence of phonons. It happens for any finite electron-phonon coupling strength at the resonance condition when the pumping frequency matches the phonon frequency, and it takes finite phonon coupling strength away from the resonance. Moreover, there exist parameter regimes with non-quantized negative and positive charge transport. The modified effective pumping path due to electron-phonon coupling accurately explains the underlying physics.

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TT 36.4 Wed 15:45 HSZ 103

Large thermal Hall effect in a disordered topological insulator — •Rohit Sharma, Mahasweta Bagchi, Oliver Breunig, Yoichi Ando, and Thomas Lorenz — II. Physikalisches Institut, Universität zu Köln, Zülpicher Straße 77, D-50937 Köln, Germany

Topological insulators mother compounds (Bi_2Se_3,Bi_2Te_3) are notorious for their high thermoelectric figure of merit and to quantify that, they have been under scrutiny in the past for their longitudinal thermal transport. Surprisingly no attention has been paid on the transverse part of heat transport. Motivated by the recent findings of thermal Hall effect in some oxide and magnetic insulators[1], we have experimentally observed a large thermal Hall effect in disordered topological insulator $TlBi_{0.15}Sb_{0.85}Te_2$[2]. By comparing thermal conductivity κ_{xx} and thermal Hall effect κ_{xy} data with the electrical counterparts (σ_{xx} & σ_{xy}), we study a possible influence of phonon drag on thermal transport. Electrical hall conductivity (σ_{xy}) shows multi-band behaviour in the whole temperature range (4-300K). Electronic contribution to thermal transport κ_e was calculated by using Wiedemann-Franz law and then compared with the measured thermal transport data, where it was found that both κ_{xx} and κ_{xy} shows phonon dominated behaviour. When compared κ_{xy} and κ_e, former shows an order of magnitude higher signal then the latter one.Possible reasons for large thermal Hall effect in $TlBi_{0.15}Sb_{0.85}Te_2$ will be discussed.

Funded by the DFG via CRC 1238 Projects A04 and B01

[1] M. Boulanger et al., Nat. Commun. 11, 5325 (2020)
[2] O. Breuning et al., Nat. Commun. 8, 15545 (2017)

TT 36.5 Wed 16:00 HSZ 103

Mixed higher-order topology: boundary non-Hermitian skin effect induced by a Floquet bulk — •Hui Liu and Ion Cosma Fulga — Leibniz Institute for Solid State and Materials Research, Dresden

We show that anomalous Floquet topological insulators generate intrinsic, non-Hermitian topology on their boundary. As a consequence, removing a boundary hopping from the time-evolution operator stops the propagation of chiral edge modes, leading to a non-Hermitian skin effect. This does not occur in Floquet Chern insulators, however, in which boundary modes continue propagating. By evaluating the local density of states, we found that the resulting non-Hermitian skin effect is critical, i.e. scale-invariant, due to the nonzero coupling between the bulk and the edge. Further, it is a consequence of the nontrivial topology of the bulk Floquet operator, which we show by designing a real-space topological invariant. Our work introduces a form of 'mixed' higher-order topology, where a bulk system characterized by Floquet topology produces a boundary system characterized by non-Hermitian topology, without the need for any added perturbations. This opens an alternate direction in the study of topological classifications, and provides a route towards generating non-Hermitian skin effects by means of periodic driving.

15 min. break

TT 36.6 Wed 16:30 HSZ 103

PT-symmetric photonic topological insulator — •Alexander Fritzsche[1,2], Tobias Biesenthal[2], Lukas Maczewsky[2], Karolin Becker[2], Max Erhardt[2], Matthias Heinrich[2], Ronny Thomale[1], Yogesh Joglekar[3], and Alexander Szameit[2] — [1]Fakultät für Physik und Astronomie, Julius-Maximilians-Universität Würzburg, Würzburg, Germany — [2]Institut für Physik, University of Rostock, Rostock, Germany — [3]Department of Physics, Indiana University-Purdue University Indianapolis (IUPUI), Indianapolis, Indiana, USA

Gain and loss are characteristic features of open or non-Hermitian systems and lead, in general, to instable, exponentially increasing and decreasing states. However, these instabilities can be avoided when parity-time (PT) symmetry is added to such arrangements. Because of its unique properties it has been tried to combine PT symmetry with the unrivalled robustness of transport in topological insulators. In this work we propose and experimentally realize a periodically driven topological insulator with two counterpropagating boundary states where gain and loss are distributed not only spatially but also temporally using photonic waveguides as the experimental platform. Here, the periodic driving allows us to circumvent the problems that have so far hindered the combination of PT symmetry and topological insulators thereby providing the missing link between these two realms.

TT 36.7 Wed 16:45 HSZ 103

Time-reversal invariant finite-size topology — •Rafael Alvaro Flores Calderon, Roderich Moessner, and Ashley Cook — Max Planck Institut for the Physics of Complex Systems, Dresden,Germany

We report finite-size topology in the quintessential time-reversal (TR) invariant systems, the quantum spin Hall insulator (QSHI) and the three-dimensional, strong topological insulator (STI): previously-identified helical or Dirac cone boundary states of these phases hybridize in wire or slab geometries with one open boundary condition for finite system size, and additional, topologically-protected, lower-dimensional boundary modes appear for open boundary conditions in two or more directions. For the quasi-one-dimensional (q(2-1)D) QSHI, we find topologically-protected, quasi-zero-dimensional (q(2-2)D) boundary states within the hybridization gap of the helical edge states, determined from q(2-1)D bulk topology characterized by topologically non-trivial Wilson loop spectra. We show this finite-size topology furthermore occurs in 1T'-WTe2 in ribbon geometries with sawtooth edges, based on analysis of a tight-binding model derived from density-functional theory calculations, motivating experimental investigation of our results. In addition, we find quasi-two-dimensional (q(3-1)D) finite-size topological phases occur for the STI, yielding helical boundary modes distinguished from those of the QSHI by a non-trivial magneto-electric polarizability linked to the original 3D bulk STI.

TT 36.8 Wed 17:00 HSZ 103

Spectral functions of a topological Fermi-Hubbard model in one dimension — •David Mikhail and Stephan Rachel — School of Physics, University of Melbourne, Parkville, VIC 3010, Australia

We study the effects of electron-electron interactions on the charge excitation spectrum of the spinful Su-Schrieffer-Heeger model, a prototype of a one-dimensional bulk obstructed topological insulator. In light of recent progress in the fabrication of dopant-based quantum simulators we focus on experimentally detectable signatures of interacting topology in finite lattices. Importantly, these semiconductor platforms allow for local high-precision measurements using scanning tunnelling spectroscopy (STS). To this end we use Lanczos-based exact diagonalization to calculate the single-particle spectral function in real space which generalizes the local density of states to interacting systems. Its spatial and spectral resolution allows for the direct investigation and identification of edge states. While the non-trivial topology is manifested in zero-energy spin-like edge excitations for any finite interaction strength, our analysis of the spectral function shows that the single-particle charge excitations are gapped out on the boundary. Despite the loss of topological protection, we find that these edge excitations are quasiparticle-like as long as they remain within the bulk gap and as such serve as an indicating signature of the correlated topological phase measurable in single-particle measurement techniques such as STS. Our results are available at Phys. Rev. B 106, 195408 (2022).

TT 36.9 Wed 17:15 HSZ 103

Topological phases of one and two Su-Schrieffer-Heeger wires on a semiconducting substrate — •Keshab Sony[1], Anas Abdelwahab[2], and Eric Jeckelmann[3] — [1]Leibniz universität, Hannover, Germany — [2]Leibniz universität, Hannover, Germany — [3]Leibniz universität, Hannover, Germany

Atomic wires deposited on semiconducting substrates attracted lots of attention in the last two decades as a platform of quasi one-dimension (1D) properties. The Su-Schrieffer-Heeger (SSH) model is one of the simplest models that manifests the typical features of topological phases in quasi 1D characterized by topological invariant (winding number) and corresponding number of zero edge states. In this study, we consider models of one and two SSH wires coupled to semiconducting three-dimensional (3D) substrates and investigate the topological phases of these models with respect to the model parameters, eg. dimerization, wire-wire coupling, wire-substrate hybridization. The phase diagram of single wire coupled to the substrate shows stability of the existing phases without substrate but with changing effectively the wire parameters. We also address the issue of how the presence of the substrate change or preserve the phase diagrams of the two-leg ladders without substrate. We discuss the local density of states for different cases we consider.

TT 36.10 Wed 17:30 HSZ 103

Thermal diode effect in Dirac hybrid junctions — •Phillip Mercebach and Pablo Burset — Autonomous University of Madrid, Madrid, Spain

Thermo-electric devices are utilized for nano-scale refrigeration or to harness waste heat to produce electric power in electronic circuits. These devices usually require semiconductor materials or complex geometries to induce thermo-electric effects which may suffer from a narrow range of operation or poor efficiency. To counteract these shortcomings, we propose a simple device consisting of a ferromagnet (F) in proximity to a Dirac semi-metal (N) creating a ballistic NFN junction with a large operating window. We theoretically study the heat and electric currents through the junction and show strong Seebeck and Peltier effects arising from the Dirac physics and Klein tunneling in the ballistic junction. We use the device's high tunability to create a thermal diode allowing for refrigeration of a hot reservoir or for power production induced by a temperature gradient. Finally, we discuss refrigeration efficiency and the effective electron cooling temperature taking into account the phonon contribution in quasi-two-dimensional materials, like graphene or topological insulators.