TT 74: Topological Insulators

Time: Thursday 15:00–18:00 Location: H 3005

TT 74.1 Thu 15:00 H 3005

Gapped Dirac cones in thin film topological insulator — •Alireza Akbari[1] and Peter Thalmeier[2] — [1]Institut für Theoretische Physik III, Ruhr-Universität Bochum, D-44801 Bochum, Germany — [2]Max Planck Institute for the Chemical Physics of Solids, 01187 Dresden, Germany

Topological insulators (TIs) have gapless Dirac cones with helical spin polarization in their surface states. Warping introduces snowflake Fermi surfaces, observed in materials like Bi_2Se_3 and Bi_2Te_3 . Quasiparticle interference (QPI) experiments on isolated TI surfaces reveal distinct features. In thin film geometries with finite tunneling between surface states, the QPI spectrum undergoes significant changes, leading to gap formation and altered spin texture. We explore variations with film thickness and their impact on backscattering processes. Introducing a step in the TI film, achieved by profiling the substrate, results in one-dimensional bound states within the hybridization gap. In an s-wave superconductor substrate, Majorana zero modes appear at step ends within the superconducting gap. Thus this simple configuration of a stepped interface between a superconductor and a TI may host Majorana zero modes effectively.
[1] Phys. Rev. Research 2 (2020) 033002.
[2] Phys. Rev. B 104 (2021) 184511.

TT 74.2 Thu 15:15 H 3005

Topological Green's function zeros — Steffen Bollmann[1], Chandan Setty[2], Urban Seifert[3], and •Elio König[1] — [1]Max-Planck Institute for Solid State Research, 70569 Stuttgart, Germany — [2]Department of Physics and Astronomy, Rice Center for Quantum Materials, Rice University, Houston, Texas 77005, USA — [3]Kavli Institute for Theoretical Physics, University of California, Santa Barbara, CA 93106, USA

The interplay of topology and strong correlations manifests itself in a plethora of exotic phenomena. Specifically, topological bands of Green's function zeros have recently attracted substantial interest. Here, we present an analytically tractable model displaying such topological bands of zeros in the fermionic Green's function when the system is tuned to a topologically ordered phase. We further demonstrate the existence of "edge states" of zeros and discuss their experimental implications, in particular when proximitized to edge states of non-interacting topological insulators. If time permits, we will also discuss transport signatures.

TT 74.3 Thu 15:30 H 3005

Nonreciprocal charge transport in nanowires of MBE-grown topological insulator /superconductor heterostructure — •Roozbeh Yazdanpanah, Jens Brede, Alexey Taskin, and Yoichi Ando — University of Cologne, Cologne, Germany

In systems with broken inversion and time reversal symmetry, magnetochiral anisotropy (MCA) leads to such nonreciprocal transport which depends both on the current amplitude and the applied magnetic field. The MCA effect in gated nanowires of a topological insulator (TI) leads to considerable current nonreciprocity[1]. Additionally, the MCA in a superconductor (SC) in the fluctuation regime also results in nonreciprocal effects, which is also the case for stacks of TI/SC[2]. We studied the combination of these two effects. For this purpose, thin films of $(Bi_{1-x}Sb_x)_2Te_3$ on $PdTe_2$ were grown in an MBE chamber and nanowires of different widths were fabricated. Second harmonics measurements were performed to study the nonreciprocal charge transport in these nanowires. A clear enhancement of the MCA was observed in a nanowire with 100-nm width even without gating.
[1] H.F. Legg et al., Nat. Nanotechnol. 17 (2022) 696.
[2] M. Masuko et al., npj Quantum Materials 7 (2022) 104.

TT 74.4 Thu 15:45 H 3005

Optical spectroscopy study of the magnetic topological insulators $Mn(Bi_{1-x}Sb_x)_2Te_4$ at ambient and high pressure — •M. Köpf[1], S. H. Lee[2,3], Z. Q. Mao[2,3,4], and C. A. Kuntscher[1] — [1]Experimentalphysik II, Institute of Physics, Augsburg University, 86159 Augsburg, Germany — [2]2D Crystal Consortium, Materials Research Institute, Pennsylvania State University, University Park, Pennsylvania 16802, USA — [3]Department of Physics, Pennsylvania State University, University Park, Pennsylvania 16802, USA — [4]Department of Materials Science and Engineering, Pennsylvania State University, University Park, Pennsylvania 16802, USA

The magnetic topological insulator $MnBi_2Te_4$ and the related materials $Mn(Bi_{1-x}Sb_x)_2Te_4$ are promising candidates for the realization of rare quantum mechanical effects due to the coexistence of topological surface states and magnetic ordering. We studied the optical response of $Mn(Bi_{1-x}Sb_x)_2Te_4$ with various Sb doping levels x at ambient and under hydrostatic pressure. Both Sb doping and pressure application cause strong effects on the electronic band structure, strongly influencing the free charge carrier dynamics, according to infrared reflectivity measurements. In the Sb-doped compounds the metallic strength decreases from x=0 to x=0.26, followed by an increase for higher x. Under hydrostatic pressure, $MnBi_2Te_4$ and the least metallic material $Mn(Bi_{0.74}Sb_{0.26})_2Te_4$ (x=0.26) show an unusual decrease in metallic character up to ∼10 GPa.

TT 74.5 Thu 16:00 H 3005

Finite Size Effects in Magnetic Topological Insulators — •Joe Winter[1,2], Bernd Braunecker[2], and Ashley Cook[1] — [1]MPI PKS 38 Nöthnitzer Straße 01187 Dresden German — [2]School of Physics and Astronomy, North Haugh, St Andrews KY16 9SS

The antiferromagnetic topological insulator phase is a foundational realization of three- dimensional topological phases of matter with magnetic order. Experimental evidence of the axion insulator phase in MnBi2Te4 for thin-film samples, a quasi-(3-1)-dimensional (q(3-1)D) geometry, therefore motivates investigation of finite-size topo- logical (FST) phases derived from the axion insulator phase. Here, we show the AFM TI does realize finite-size topological phases for the q(3-1)D geometry, with open-boundary conditions and small system size in one direction. We first characterize the FST phase diagram in the q(3-1)D bulk using Wannier spectral flow. We also confirm the defining response signature of the underly- ing 3D AFM TI phase, due to the topologically non-trivial magnetoelectric polarizability, persists in this geometry but only for the topologically non-trivial finite-size topological regions. We then open boundary conditions in a second direction to confirm the additional bulk-boundary corre- spondence of the finite-size topological phases, finding q(3-2)D topologically-protected, gapless edge modes. The co-existence of the q(3-2)D topologically non-trivial edge states with a topological response associated with the 3D bulk topological invariant, the magnetoelectric polarizability, further demonstrates that finite-size topology is a generic feature of topological phases and very relevant experimentally.

TT 74.6 Thu 16:15 H 3005

Magnetic Topological Transistor — •Hai-Peng Sun[1,5], Chang-An Li[1,5], Sang-Jun Choi[1,5], Song-Bo Zhang[2], Hai-Zhou Lu[3,4], and Björn Trauzettel[1,5] — [1]Institute for Theoretical Physics and Astrophysics, University of Würzburg, Würzburg 97074, Germany — [2]Department of Physics, University of Zürich, Winterthurerstrasse 190, Zürich 8057, Switzerland — [3]Shenzhen Institute for Quantum Science and Engineering and Department of Physics, Southern University of Science and Technology (SUSTech), Shenzhen 518055, China — [4]Shenzhen Key Laboratory of Quantum Science and Engineering, Shenzhen 518055, China — [5]Würzburg-Dresden Cluster of Excellence ct.qmat, Germany

We propose a magnetic topological transistor based on MnBi2Te4, in which the "on" state (quantized conductance) and the "off" state (zero conductance) can be easily switched by changing the relative direction of two adjacent electric fields (parallel vs. antiparallel) applied within a two-terminal junction. We explain that the proposed magnetic topological transistor relies on a novel mechanism due to the interplay of topology, magnetism, and layer degrees of freedom in MnBi2Te4. Its performance depends substantially on film thickness and type of magnetic order. We show that "on" and "off" states of the transistor are robust against disorder due to the topological nature of the surface states. Our work opens an avenue for applications of layer-selective transport based on the topological van der Waals antiferromagnet MnBi2Te4.

15 min. break

TT 74.7 Thu 16:45 H 3005

Topological-insulator spin transistor — •Linh T. Dang[1], Oliver Breunig[1], Zhiwei Wang[1,3], Henry F. Legg[2], and Yoichi Ando[1] — [1]Physics Institute II, University of Cologne, D-50937 Köln, Germany — [2]Department of Physics, University of Basel, CH-4056 Basel, Switzerland — [3]School of Physics, Beijing Institute of Technology, Beijing 100081, China

A net spin polarization can be induced by injecting charge current into the spin-momentum-locked surface state of topological insulators (TIs). Due to the helical spin structure of this surface state, only one sign of spin polarization is expected from a fixed current direction. However, both signs that agree and disagree with this prediction have been observed in the past. Although the origin of the opposite sign is unclear, it suggests that the spin polarization can be switched from one sign to the other. In this talk, we report our experiment in which we observed both signs of spin polarization in the same device at different back-gate voltages, which demonstrates the ability to switch between the two signs by electrostatic gating; which gives a proof of principle of a spin transistor based on TI [1]. We observed a complicated switching behaviour which can be explained by a minimal model taking into account the competing contributions of the topological surface state and trivial Rashba-split bands.

[1] L. T. Dang, O. Breunig, Z. Wang, H. F. Legg, Y. Ando, Phys. Rev. Appl. 20 (2023) 024065.

TT 74.8 Thu 17:00 H 3005

Structure-driven phase transitions in paracrystalline topological insulators — Victor Regis[1], Victor Velasco[2], Marcello Silva Neto[2,3], and •Caio Lewenkopf[4] — [1]Jožef Stefan Institute, Ljubljana, Slovenia — [2]Instituto de Física, Universidade Federal do Rio de Janeiro, Rio de Janeiro, Brazil — [3]Laboratório Nacional de Nanotecnologia - CNPEM, Campinas, Brazil — [4]Instituto de Física, Universidade Federal Fluminense, Niterói, Brazil

We study phase transitions driven by structural disorder in noncrystalline topological insulators. We use a procedural generation algorithm, the Perlin noise, typically used in computer graphics, to introduce disorder in a two-dimensional lattice, allowing a continuous interpolation between a pristine and a random gas system, going through all different intermediate structural regimes, such as the paracrystalline and the amorphous phases. We apply a two-band model, including intraorbital and interorbital mixings, to the structures generated by the algorithm and we find a sequence of structure-driven topological phase transitions characterized by changes in the topological Bott index, at which the insulating gap dynamically closes while evolving from the Bragg planes of the Brillouin zone towards the center. We interpret our results within the framework of Hosemann's paracrystal theory, according to which distortion is included in the lattice structure factor and renormalizes the band-splitting parameter. Based on these results, we ultimately demonstrate the phenomenon of topological protection at its extreme.

TT 74.9 Thu 17:15 H 3005

Physical consequence of edge zeros in topological Mott insulators — •Niklas Wagner[1], Daniele Guerci[2], Andrew J. Millis[2,3], and Giorgio Sangiovanni[1] — [1]Institut für Theoretische Physik und Astrophysik, Universität Würzburg, 97074 Würzburg, Germany — [2]Center for Computational Quantum Physics, Flatiron Institute, New York, USA — [3]Department of Physics, Columbia University, New York, USA

Recently, Green's function zeros and their relation to topology have attracted considerable interest [1-4]. Using slave-rotor calculations I will demonstrate a connection between gapless zeros and gapless spinons – both in the bulk and at the boundary. I will then apply these results to interfaces between topological insulators and topological Mott insulators, showing that the previously observed annihilation of edge zeros and egde poles [4] can be interpreted using the spinon language. This approach reveals the occurance of a spin-charge separation at the interface.

[1] A. Blason and M. Fabrizio, arxiv:2304.08180(2023)
[2] J. Zhao, P. Mai, B. Bradlyn, P. Phillips, arXiv:2305.02341 (2023)
[3] C. Setty et al., arXiv:2309.14340 (2023)
[4] N.Wagner et al., Nat. Commun. 14, 7531 (2023)

TT 74.10 Thu 17:30 H 3005

A gate-tunable bosonic Su-Schrieffer-Heeger chain — •Lukas Johannes Splitthoff[1,2], Miguel Carrera Belo[1,2], Guliuxin Jin[2], Eliska Greplova[2], and Christian Kraglund Andersen[1,2] — [1]QuTech, Delft University of Technology, Delft 2628 CJ, The Netherlands — [2]Kavli Institute for Nanoscience, Delft University of Technology, Delft 2628 CJ, The Netherlands

Metamaterials engineered to host topological states of matter in controllable quantum systems hold promise for quantum simulations and the advancement of quantum computing technologies. In this context, the Su-Schrieffer-Heeger (SSH) chain, a textbook example of topological matter, has gained prominence due to its simplicity and practical applications, including entanglement stabilization in superconducting quantum circuits. In this talk, we present the implementation of a five-unit-cell bosonic SSH chain on a one-dimensional lattice of superconducting resonators. Our approach offers precise and independent in-situ tuning of coupling parameters a feature that has eluded previous work. We achieve electrostatic control over the inductive intercell coupling using semiconductor nanowire junctions, which enables the spectroscopic observation of a trivial-to-topological phase transition in the engineered topological metamaterial. In particular, we will discuss the robustness of the topological edge state against various disorder realizations, including local perturbations and noise originating from electrostatic gate control. Our results pave the way for larger controllable bosonic lattices to facilitate quantum simulations.

TT 74.11 Thu 17:45 H 3005

Transport channels in the two-dimensional, Floquet-driven Qi-Wu-Zhang model — •Aya Abouelela[1], Haixin Qiu[2], and Johann Kroha[1,3] — [1]Universität Bonn, Germany — [2]Georg August Universität Göttingen, Germany — [3]University of St. Andrews, U.K

This presentation explores the realm of topological phases, with a specific focus on topological insulators and their edge states. Over the past decade, the field has witnessed rapid developments in the external drive of these systems, with periodically driven or Floquet systems standing out for their ability to induce diverse topological phases through a seemingly simple dynamical control. Our talk centers on anomalous Floquet topological phases within a hopping-driven Qi-Wu-Zhang model. We showcase the impact of drive parameters such as amplitude, frequency, and on-site potential on band Chern numbers, unveiling the emergence of anomalous edge states. Utilizing Chern number phase diagrams, we present edge states with vanishing dynamical winding numbers or Chern numbers. Additionally, we propose experimentally realizable slab geometry of our model with finite bias voltage and predict dI/dV spectroscopy exhibiting quantized transport carried by the zero and anomalous modes. Finally, we map out the spatial structure of the transport channels and highlight the transmission along the system's physical edge. Notably, the slab geometry exhibits corner sites with a high density of states, which may originate from higher order corner states.