TT 18: Topological Insulators

Time: Wednesday 9:30–11:45 Location: H23

TT 18.1 Wed 9:30 H23

Exceptional topological insulators — •Michael Denner[1], Anastasiia Skurativska[1], Frank Schindler[1,2], Mark Fischer[1], Ronny Thomale[3], Tomás Bzdusek[1,4], and Titus Neupert[1] — [1]Department of Physics, University of Zurich, Switzerland — [2]Princeton Center for Theoretical Science, Princeton University, USA — [3]Institut für Theoretische Physik und Astrophysik, Universität Würzburg, Germany — [4]Condensed Matter Theory Group, Paul Scherrer Institute, Switzerland

Since their theoretical conception and experimental discovery, 3-dimensional topological insulators have become the focal point for research on topological quantum matter. Their key feature is a single Dirac electron on the surface, representing an anomaly: in purely 2D such a state can neither be regularized on a lattice nor in the continuum. I will introduce an analog in dissipative systems, which are described by non-Hermitian operators, the exceptional topological insulator (ETI). Like normal topological insulators, the ETI hosts exotic surface states. It is characterized by a bulk energy point gap and exhibits robust surface states that cover the bulk gap as a single sheet of complex eigenvalues or with a single exceptional point. Even though it does not require any symmetry to be stabilized, I will explain how this non-Hermitian topological phase can also be inferred using symmetry-indicators of the bulk Hamiltonian. Furthermore, I will demonstrate how the ETI can be induced in gapless solid-state systems and metamaterials, thereby setting a paradigm for non-Hermitian topological matter.

TT 18.2 Wed 9:45 H23

Berry curvature effects in high-harmonic generation in topological insulator surface states — •Vanessa Junk[1], Cosimo Gorini[2], and Klaus Richter[1] — [1]Institut für Theoretische Physik, Universität Regensburg, Germany — [2]Université Paris-Saclay, CEA, CNRS, SPEC, 91191, Gif-sur-Yvette, France

When strong-field light is interacting with a solid, it acts as an a.c. bias accelerating electrons through the bandstructure and driving non-perturbative transitions. These processes can lead to the emission of high-order harmonics containing fingerprints of the materials properties. Since in topological insulator surface states scattering is strongly suppressed, signatures of coherent transport can be found in the resulting spectra.

Recently, high-harmonics generation from the surface states of the three-dimensional topological insulator Bi_2Te_3 has been observed experimentally [1]. Here, we show fully quantum mechanical simulations of the electron dynamics and compare them with the experimental results. We find that the Berry curvature can not only lead to high-harmonics polarized perpendicularly to incoming radiation but also to an alternating polarization of odd and even order harmonics. This being one of the key observations in the experiment suggests the importance of Berry curvature effects in coherent high-harmonics emission.

[1] C. Schmid, L. Weigl, P. Grössing, V. Junk, C. Gorini, S. Schlauderer, S. Ito, M. Meierhofer, N. Hofmann, D. Afanasiev, J. Crewse, K. Kokh, O. Tereshchenko, J. Güdde, F. Evers, J. Wilhelm, K. Richter, U. Höfer, R. Huber, Nature **593**, 385 (2021)

TT 18.3 Wed 10:00 H23

Spin-polarized surface state transport in gate-tunable topological insulator — •Linh Dang[1], Oliver Breunig[1], Henry Legg[2], and Yoichi Ando[1] — [1]1 II. Physikalisches Institut, Universität zu Köln, Zülpicher Str. 77, 50937 Köln, Germany — [2]Department of Physics, University of Basel, Klingelbergstrasse 82, CH-4056 Basel, Switzerland

Topological insulators (TIs) possess helical spin-momentum locked surface states that can be harnessed to create a non-zero spin polarization by applying a current through the TI. Two opposite types of spin polarization have been reported on the same material, suggesting the interplay between topological surface state and Rashba spin splitting state of 2-dimensional surface electrons. These two contributing effects might be used to create a spin transistor device. In this report, we discuss the sign switching of the spin polarization by electrostatic gating based on data acquired from devices that were microfabricated on TI flakes.

TT 18.4 Wed 10:15 H23

Chern insulating phases and thermoelectric properties of EuO/MgO(001) superlattices — •Okan Koeksal and Rossitza Pentcheva — Department of Physics and Center of Nanointegration (CENIDE), University of Duisburg-Essen, 47057 Duisburg

The effect of confinement and strain on the topological and thermoelectric properties of $(EuO)_n/(MgO)_m(001)$ superlattices (SLs) are investigated by means of DFT + U + spin-orbit coupling (SOC) calculations in conjunction with semi-classical Boltzmann transport theory. A particularly strong effect is observed in the ferromagnetic $(EuO)_1/(MgO)_3(001)$ SL at the lateral lattice constant of MgO ($a = 4.24$ Å) where SOC opens a band gap of 0.51 eV due to an inversion between occupied localized Eu $4f$ and itinerant $5d$ conduction bands. This band inversion between bands of opposite parity is accompanied by a spin reorientation in the spin-texture along the contour of band surrounding the Γ point. The resulting Chern insulating phase with $C = -1$, confirmed by a single topological edge state, exhibits promising thermoelectric properties, i.e., a high Seebeck coefficient between 400 and 800 μVK^{-1}. Somewhat lower thermoelectric values are obtained for the ferromagnetic semimetallic $(EuO)_2/(MgO)_2(001)$ SL, where SOC also induces a band inversion and AHC with values up to –1.04 e^2/h. This work emphasizes the correlation between non-trivial topology and thermoelectricity in $(EuO)_n/(MgO)_m(001)$ SLs with broken time-reversal symmetry [1].

Support by the DFG within CRC/TRR80, project G3 is gratefully acknowledged.

[1] O. Köksal and R. Pentcheva, Phys. Rev. B **103**, 045135 (2021)

TT 18.5 Wed 10:30 H23

Stacking faults in weak topological insulators with time reversal symmetry — •Gabriele Naselli, Viktor Könye, and Ion Cosma Fulga — Leibniz-Institut für Festkörper-und Werkstoffforschung, Dresden, Germany

In experimental observation stacking faults can play a significant role in hiding the topological properties of topological insulators. The defects break lattice symmetries which can be required for the protection of the topological states in weak topological insulators. We studied stacking faults in $3D$ weak topological insulators like Bi_2TeI and $Bi_{14}Rh_3I_9$. Both these materials are formed by $2D$ topological insulating layers (with time reversal symmetry and quantum spin Hall effect) stacked on top of each other in the z direction with trivial insulating spacers between them. We have built a simple tight binding model for both of these materials and got the topological properties solving the eigenvalue problem numerically. We introduced a stacking fault in our model by shifting half of the system by a fraction of the unit cell in the z direction. We mapped the stacking surface in the WTI into a Su-Schrieffer-Heeger chain, considering the effective hoppings between the TI layers on the left and right side of the stacking fault. When all the TI layers on the left side are strongly interacting with the TI layers on the right side of the defect the corresponding SSH model is in the trivial phase and we did not find conducting states. Instead when the stacking fault has two weakly interacting TI layers at its boundaries the corresponding SSH chain is in the topological phase and we have found localized conducting states at the defect.

TT 18.6 Wed 10:45 H23

Dynamic impurities in two-dimensional topological insulator edge states — •Simon Wozny[1], Martin Leijnse[1], and Sigurdur I. Erlingsson[2] — [1]Division of Solid State Physics and NanoLund, Lund University, Box 118, S-22100 Lund, Sweden — [2]School of Science and Engineer- ing, Reykjavik University, Menntavegi 1, IS-101 Reykjavik, Iceland

Two-dimensional topological insulators host one-dimensional helical states at the edges. These are characterized by spin-momentum locking and time-reversal symmetry protects the states from backscattering by potential impurities. Magnetic impurities break time-reversal symmetry and allow for backscattering.

We have investigated the effects of random, aligned but harmonically rotating magnetic impurities. Using the time dependent Green's function (GF) for the system we calculate the time-averaged density of states (DOS) and extract the transmission via a Floquet scattering formalism. For slow driving the DOS and transmission match an aver-

age over static impurity orientations, whereas fast driving results in a flat low-energy DOS and transmission with resonances at higher energies related to Floquet sub-band crossings. Resonant driving leads to a nontrivial DOS and transmission. We also investigate the dependence on the ratio between potential and magnetic strength of the impurities.

TT 18.7 Wed 11:00 H23

Quantum phase transitions and a disorder-based filter in a Floquet system — •Bhargava Balaganchi Anantha Ramu, Sanjib Kumar Das, and Ion Cosma Fulga — IFW Dresden and Wurzburg-Dresden Cluster of Excellence ct.qmat, Helmholtzstrasse 20, 01069 Dresden, Germany

Two-dimensional periodically-driven topological insulators have been shown to exhibit numerous topological phases, including ones which have no static analog, such as anomalous Floquet topological phases. We study a two dimensional model of spinless fermions on a honeycomb lattice with periodic driving. We show that this model exhibits a rich mixture of weak and strong topological phases, which we identify by computing their scattering matrix invariants. Further, we do an in-depth analysis of these topological phases in the presence of spatial disorder and show the relative robustness of these phases against imperfections. Making use of this robustness against spatial dis-order, we propose a filter which allows the passage of only edge states, and which can be realized using existing experimental techniques.

TT 18.8 Wed 11:15 H23

Topological phases of Su-Schrieffer-Heeger alternating ladders — •Anas Abdelwahab — Leibniz Universität Hannover, Hannover, Germany

Alternating ladders are constructed from unit cells consisting of rungs with odd number of sites connected with rungs with even number of sites [1]. These systems can be constructed using several options of equivalent unit cells. Two one-site rungs connected with two two-site rungs as well as two three-site rungs connected with two two-site rungs are investigated. Rich phase diagrams of topological insulating phases separated by critical lines are identified using the Su-Schrieffer-Heeger (SSH) model that describe such ladder systems. The phase diagrams depend on the choices between the equivalent unit cells. One could identify cases with flat bands close to the Fermi level. In principle, these simple models can be realized in designer quantum materials such as artificial lattices constructed by manipulation of atoms using a tip of scanning tunnelling microscope (STM) [2,3].

[1] K. Essalah, A. Benali, A. Abdelwahab, E. Jeckelmann, and R. T. Scalettar, Phys. Rev. B 103, 165127 (2021)
[2] R. Drost, T. Ojanen, A. Harju and P. Liljeroth, Nat. Phys. 13, 668 (2017)
[3] M. N. Huda, S. Kezilebieke, T. Ojanen, R. Drost and P. Liljeroth, npj Quantum Materials 5, 17 (2020)

TT 18.9 Wed 11:30 H23

Coulomb-blockade spectroscopy in topological insulator-superconductor hybrid devices — •Benedikt Frohn, Tobias W. Schmitt, Wilhelm Wittl, Dennis Heffels, Michael Schleenvoigt, Abdur R. Jalil, Detlev Grützmacher, and Peter Schüffelgen — Peter Grünberg Institut, Forschungszentrum Jülich & JARA Jülich-Aachen Research Alliance, D-52425 Jülich, Germany

In the search for fault tolerant quantum computing, Majorana zero modes resemble a promising platform [1]. We investigate an island of a topological insulator (TI) nanoribbon, $(Bi,Sb)_2Te_3$, proximitized with a superconductor (S) for signatures of these states using Coulomb-blockade spectroscopy. One possible signature would be a change in charge periodicity once the island is tuned into the topological regime. We successfully created tunneling barriers made from Al_2O_3 and obtained the characteristic Coulomb diamond structure. Nb provides excellent interface transparency towards TI and was capped *insitu*, yet we found no change in charge periodicity. Al, however, is known to show these signatures in comparable experiments. Since Al diffuses heavily into the TI when put directly into contact, we fabricated Josephson junctions (JJs) with different thin interlayers between $(Bi,Sb)_2Te_3$ and Al to characterize the influence of these diffusion barriers on the transport properties of the JJs. We find four possible interlayers that allow for engineering a transparent S-TI interface. These results will enable us to perform Coulomb-blockade experiments with Al as a S.

[1] A.Y. Kitaev, Ann. Phys. 303, 2 (2003)