TT 1: Topological Insulators 1 (joint session TT/HL)

Time: Monday 9:30–12:45 Location: HSZ 03

TT 1.1 Mon 9:30 HSZ 03

2D to 3D crossover in topological insulators — Corentin Morice, •Thilo Kopp, and Arno P. Kampf — University of Augsburg, Augsburg, Germany

At the heart of the study of topological insulators lies a fundamental dichotomy: topological invariants are defined in infinite systems, but their main footprint, surface states, only exists in finite systems. In systems in the slab geometry, namely infinite in two dimensions and finite in one, the 2D topological invariant was shown to display three different types of behaviours. In the limit of zero Dirac velocity along z, these behaviours extrapolate to the three 3D topological phases: trivial, weak and strong topological insulators. We show analytically that the boundaries of these regions are topological phase transitions of particular significance, and allow one to fully predict the 3D topological invariants from finite-thickness information. Away from this limit, we show that a new phase arises, which displays surface states but no band inversion at any finite thickness, disentangling these two concepts closely linked in 3D.

TT 1.2 Mon 9:45 HSZ 03

Correlated Ground States in Maximally Symmetric Flat Bands of 2D Topological Insulators — •Nikolaos Stefanidis and Inti Sodemann — Max-Planck-Institut für Physik komplexer Systeme,Nöthnitzer Str. 38, 01187 Dresden

We study the many body-problem in partially filled topological flat bands that are maximally symmetric realisations of two dimensional time-reversal invariant insulators. These bands can be viewed as two flat bands with opposite Chern numbers that are forced to be degenerate by time-reversal-symmetry. For half-filled bands we develop a mean field description of states that spontaneously break time reversal symmetry and their competition with translationally broken symmetry states and superconductors. At general fillings we prove a rigorous theorem dictating the absence of exact topological degeneracy for any translational and time reversal invariant two-body Hamiltonian. We also solve exactly the two body problem, which turns out to display a remarkable correlation between the center-of-mass and relative-coordinate degrees of freedom of the two particles.

TT 1.3 Mon 10:00 HSZ 03

Dynamic impurities in two-dimensional topological insulator edge states — •Simon Wozny[1], Martin Leijnse[1], Karel Vyborny[4], Wolfgang Belzig[3], 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 Engineering, Reykjavik University, Menntavegi 1, IS-101 Reykjavik, Iceland — [3]Fachbereich Physik, Universität Konstanz, D-78457 Konstanz, Germany — [4]Institute of Physics, Academy of Science of the Czech Republic, Cukrovarnická 10, Praha 6, Czech Republic

Two-dimensional topological insulators give 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. In an earlier work we investigated the effects of random, static, aligned magnetic impurities [1] on the spectrum and found that for fixed magnetic impurity strength the gap in the density of states closes with rising potential strength. We are now moving on to investigate the effect of random, aligned but harmonically rotating magnetic impurities. This is done by calculating the density of states via the time dependent Green's function for the system.

[1] S. Wozny, K. Vyborny, W. Belzig, and S. I. Erlingsson, Phys. Rev. B 98, 165423 (2018)

TT 1.4 Mon 10:15 HSZ 03

Topology and boundary physics in one dimensionional insulators — •Herbert Schoeller, Niclas Müller, Dante Kennes, and Mikhail Pletyukhov — RWTH Aachen University, Germany

Alternative to the characterization of topological insulators in terms of mathematical invariants we present a practical version via the explicit solution of the Schrödinger equation for a generic half-infinite system in one dimension. We show how the boundary condition can be fulfilled by taking appropriate linear combinations of Bloch eigenstates for the infinite system with complex quasimomentum [1]. Via this scheme all edge and bulk states can be explicitly constructed. In the presence of chiral or particle-hole symmetry the existence and stability of zero-energy edge states together with the bulk-boundary correspondence is established, proving the consistency with the standard classification scheme. Without symmetry constraints, we find generically edge states at finite energy in the gap and show that many bulk states are superpositions of Boch waves and exponentially decaying parts, implying interesting boundary physics at finite energy [2].

[1] D.M. Kennes et al., Phys. Rev. B 100, 041103 (2019).

[2] N. Müller et al., arXiv:1911.02295.

TT 1.5 Mon 10:30 HSZ 03

Topological invariants to characterize universality of boundary charge in one-dimensional insulators beyond symmetry constraints — •Mikhail Pletyukhov[1], Dante Kennes[1], Jelena Klinovaja[2], Daniel Loss[2], and Herbert Schoeller[1] — [1]RWTH Aachen University, Germany — [2]University of Basel, Switzerland

We address universal properties of the boundary charge Q_B for a wide class of tight-binding models with non-degenerate bands in one dimension [1]. We provide a precise formulation of the bulk-boundary correspondence by splitting Q_B via a gauge invariant decomposition in a Friedel, polarisation, and edge part. We reveal the topological nature of Q_B by proving the quantization of a topological index $I = \Delta Q_B - \bar{\rho}$, where ΔQ_B is the change of Q_B when shifting the lattice by one site towards a boundary and $\bar{\rho}$ is the average charge per site. For a single band we find this index to be given by the winding number of the fundamental phase difference of the Bloch wave function between two adjacent sites. For a given chemical potential we establish a central topological constraint $I \in \{-1, 0\}$ related to charge conservation and particle-hole duality.

[1] M. Pletyukhov et al, arXiv: 1911.06886, 1911.06890

TT 1.6 Mon 10:45 HSZ 03

Interaction effects in band insulators with topological properties — •Yen-Ting Lin, Volker Meden, Herbert Schoeller, and Dante M. Kennes — Institute for Theory of Statistical Physics, RWTH Aachen, and JARA- Fundamentals of Future Information Technology

One-dimensional models for band insulators such as the Su-Schrieffer-Heeger model or the Rice-Mele model currently regain attention as they show topological properties. We investigate the spinless versions of these models complemented by a two-particle interaction. To study the bulk as well as boundary and topological properties we use the functional renormalization group. The bulk gap shows the interaction dependent scaling predicted by an effective field theory. The density oscillations of an open boundary are modified by the interaction. The decay length of the exponential part is reduced and the inverse square root behavior of the pre-exponential function is altered. In addition, we present results for the boundary charge and the local single-particle spectral function.

TT 1.7 Mon 11:00 HSZ 03

Magnetoconductance, Quantum Hall Effect, and Coulomb Blockade in Topological Insulator Nanowires — •Raphael Kozlovsky, Ansgar Graf, Denis Kochan, Klaus Richter, and Cosimo Gorini — Institut für Theoretische Physik, Universität Regensburg, 93040 Regensburg, Germany

Three-dimensional topological insulator (3DTI) nanowires host topologically non-trivial surface states wrapped around an insulating bulk. We investigate the transport properties of such wires subject to external electric and magnetic fields using effective surface Dirac Hamiltonians. By considering shaped (tapered, curved) 3DTI nanowires, we go beyond the well-studied cylindrical geometry [1] and thereby access intriguing mesoscopic transport phenomena: While the conductance of a wire in perpendicular magnetic field is in general quantized due to higher-order topological hinge states, the conductance in longitudinal magnetic field depends on the precise wire geometry. For rotationally symmetric nanowires with varying radius, a coaxial magnetic field leads to a spatial variation of the enclosed magnetic flux giving rise to a non-trivial mass potential along the wire direction. Depending on the radial profile of the wire, this mass potential leads, for instance, to a conductance governed by the transmission through Dirac Landau levels, or to Coulomb blockade.

[1] arxiv:1909.13124 (2019)

15 min. break.

TT 1.8 Mon 11:30 HSZ 03

Electronic structure and properties of the surface of $TlBiSe_2$ in dependence on the coverage by Fe — •Svitlana Polesya[1], Sergiy Mankovsky[1], Alexander Liebig[2], Franz Giessibl[2], and Hubert Ebert[1] — [1]Dept. Chemistry, LMU Munich, Butenandtstrasse 11, D-81377 Munich, Germany — [2]Inst. Expt. and Appl. Physics, University Regensburg, Regensburg, Germany

We will present the results of investigations on the electronic structure of the surface of of the topological insulator $TlBiSe_2$ with different terminations by means of the tight binding KKR band structure method (TB KKR). The appearance of the topologically protected surface states at the Γ point is found in agreement with ARPES experiment. The modification of these states due to Fe adatoms deposited on top of the surface having different terminations, was investigated as a function of the degree of surface coverage by Fe. This study was performed via the CPA (Coherent Potential Approximation) alloy theory, assuming random occupation of the surface positions by Fe. The exchange coupling parameters have been calculated for different amount of Fe atoms covering the surface in order to determine the magnetic structure of the Fe overlayer, that can be probed by STM experiments.

TT 1.9 Mon 11:45 HSZ 03

MBE-grown Sb_2Te_3/Bi_2Te_3 heterostructures - Tuning of the topological surface states — Vanda M. Pereira, Chi-Nan Wu, Liu Hao Tjeng, and •Simone G. Altendorf — Max Planck Institute for Chemical Physics of Solids, Dresden, Germany

Topological insulators (TIs) are bulk insulators with the bulk band gap only intersected by conducting, Dirac-cone like surface states that are topologically protected. For many materials, the Dirac point of these surface states lays buried in the bulk bands which hinders an experimental observation of the various theoretically predicted topological quantum effects, like the quantum anomalous Hall effect.

In our study, we combine two TIs, namely Sb_2Te_3 and Bi_2Te_3, in a heterostructure which allows for a tuning of the position of the Dirac point to the Fermi level by varying the layer thicknesses. Using the optimized layer structure, we investigate the changes of the TI properties when interfaced with a magnetic substrate. We will present a characterization of the MBE-grown Sb_2Te_3/Bi_2Te_3 heterostructures on non-magnetic and magnetic substrates by RHEED, XPS, ARPES, XMCD, and transport measurements.

TT 1.10 Mon 12:00 HSZ 03

Topological insulator interfaced with ferromagnetic insulators: Bi_2Te_3 thin films on magnetite and iron garnets — V. M. Pereira[1], S. G. Altendorf[1], C. E. Liu[1], S. C. Liao[1], A. C. Komarek[1], M. Guo[2], H. -J. Lin[3], C. T. Chen[3], M. Hong[4], J. Kwo[2], L. H. Tjeng[1], and •C. N. Wu[1,2] — [1]MPI CPfS, Dresden, Germany — [2]Dept. of Phys., NTHU, Hsinchu, Taiwan — [3]NSRRC, Hsinchu, Taiwan — [4]Dept. of Phys., NTU, Taipei, Taiwan

We report on our study about the growth and characterization of Bi_2Te_3 thin films on top of $Y_3Fe_5O_{12}(111)$, $Tm_3Fe_5O_{12}(111)$, $Fe_3O_4(111)$, and $Fe_3O_4(100)$ single crystal substrates. Using molecular beam epitaxy, we were able to prepare the topological insulator / ferromagnetic insulator heterostructures with no or minimal chemical reaction at the interface. We observed the anomalous Hall effect on these heterostructures and also a suppression of the weak antilocalization in the magnetoresistance, indicating a topological surface state gap opening induced by the magnetic proximity effect. However, we did not observe any obvious x-ray magnetic circular dichroism (XMCD) on the Te M_{45} edges. The results suggest that the ferromagnetism induced by the magnetic proximity effect via Van der Waals bonding in Bi_2Te_3 is too weak to be detected by XMCD, but still can be observed by electrical transport measurements. This is in fact not inconsistent with reported density-functional calculations on the size of the gap opening.

TT 1.11 Mon 12:15 HSZ 03

Time dependent Rashba coupling at the helical edge — •Lorenzo Privitera[1], Niccolò Traverso ZIani[2], Simone Barbarino[3], Jan Carl Budich[3], and Björn Trauzettel[1] — [1]Institute for Theoretical Physics, University of Würzburg, 97074 Würzburg, Germany — [2]Dipartimento di Fisica, Università di Genova, and SPIN-CNR, Via Dodecaneso 33, 16146 Genova, Italy — [3]Institute of Theoretical Physics, Technische Universität Dresden, 01062 Dresden, Germany

Time-dependent effects in the edges of quantum spin Hall insulators (QSHI) have been the subject of intense research in the last years. In particular, it was recently pointed out that the interplay of electromagnetic temporal noise with Rashba impurities might play a prominent role in the observed breaking of perfect conductance quantization. In this work we study the conductance of a QSHI edge subjected to the time-periodic oscillations of the strength of a single Rashba impurity. We investigate the perturbative regime of the impurity and examine the effects of repulsive interactions through bosonization. The resulting backscattering current is the sum of three different power laws in driving frequency and voltage, marking a clear distinction from non-helical Luttinger liquids. Furthermore, we find that backscattering can become stronger for weak interactions upon tuning the frequency of the driving. Our results provide a further step in the understanding of time-dependent perturbations in 1d electronic liquids and are of particular interest in view of the technological applications arising from the time-dependent manipulation of topological edge states.

TT 1.12 Mon 12:30 HSZ 03

Thermoelectric effects in a helical edge coupled to a quantum magnet — •Peter Silvestrov[1], Piet Brouwer[2], and Patrik Recher[1,3] — [1]Institute for Mathematical Physics, TU Braunschweig, 38106 Braunschweig, Germany — [2]Physics Department and Dahlem Center for Complex Quantum Systems, Freie Universität Berlin, Arnimallee 14, 14195 Berlin, Germany — [3]Laboratory for Emerging Nanometrology Braunschweig, 38106 Braunschweig, Germany

We explore the analogy between a helical edge current interacting with a microscopic magnet and the adiabatic quantum motor[1-3], with special emphasis on thermal effects. These include a thermal engine, in which the thermal gradient is converted directly into mechanical work, a device producing an AC current from the temperature gradient, and an electron refrigerator.

[1] Q. Meng, S. Vishveshwara, and T. L. Hughes, Phys. Rev. B **90**, 205403 (2014).
[2] L. Arrachea and F. von Oppen, Physica E **74**, 596 (2015).
[3] P. G. Silvestrov, P. Recher, and P. W. Brouwer, Phys. Rev. B **93**, 205130 (2016).