TT 18: Poster Session: Topological Topics (joint session TT/MA)

Time: Monday 15:00–18:30 Location: Poster D

TT 18.1 Mon 15:00 Poster D

Helical edge state interferometry in a quantum spin Hall insulator — •Raul Stühler, André Kowalewski, Felix Reis, Johannes Weis, Jörg Schäfer, and Ralph Claessen — Physikalisches Institut (EP4) der Universität Würzburg, 97074 Würzburg, Germany

Since the discovery of the quantum spin Hall (QSH) effect, two-dimensional topological insulators (2D-TI) have constituted a promising system for spintronics and ballistic electronic transport. The latter property of 2D-TIs is based on exceptional quantum coherence of helical edge state electrons in the absence of time-reversal symmetry breaking. Notwithstanding, quantum interference between helical edge state electrons becomes relevant when a multitude of helical edge state pairs are being brought into direct proximity in a nano-constriction. Here we present the realization of a helical edge state nano-constriction embedded in the high-temperature 2D-TI bismuthene [1], formed by an anti-phase domain boundary of limited extent. Via STS, we prove quantum interference between counter propagating helical electrons and make use of an analogy to a Fabry-Pérot electronic resonator. Such interplay between quantum coherence and interference might be further exploited, e.g., as a controllable charge and spin current switch operated with gate voltages instead of magnetic fields [2].

[1] F. Reis et al., Science 357, 287-290, (2017)
[2] P. Sternativo, F. Dolcini, Phys. Rev. B 89, 035415 (2014).

TT 18.2 Mon 15:00 Poster D

Potassium-Induced n-Doping of the High-Temperature Quantum Spin Hall System Bismuthene on SiC(0001) — •Johannes Weis, André Kowalewski, Felix Reis, Raul Stühler, Felix Spriestersbach, Lenart Dudy, Victor Rogalev, Jörg Schäfer, and Ralph Claessen — Physikalisches Institut und Röntgen Center for Complex Material Systems, Universität Würzburg, D-97074 Würzburg, Germany

Bismuthene, a monolayer of Bi-atoms bonded onto a SiC(0001) substrate in a honeycomb lattice, has recently been experimentally realized [1]. This 2D system has a large band gap of approx. 0.8 eV and is a most promising candidate for the realization of the quantum spin Hall effect at room-temperature. Theoretical tight-binding and DFT calculations consistently predict the existance of helical edge states forming Dirac branches. While Reis et al. [1] showed proof for 1D metallic edge states spanning the 2D bulk band gap by means of STM and STS, up to date a direct experimental observation of the linear electron dispersion has not been reported and ARPES would be highly desirable.

One major obstacle here is the Fermi level being too close to the 2D bulk valence band maximum. Here we present the adsorption of potassium as a tool to shift the Fermi level above the predicted Dirac point in a controlled way. The effect of the dopant has been investigated both on an atomic level by STM and STS and spacially integraged by ARPES.

[1] F. Reis *et al.*, Science 357,287-290 (2017)

TT 18.3 Mon 15:00 Poster D

Electronic correlation effects on double Dirac semimetals — •Niklas Wagner[1], Domenico Di Sante[1], Sergio Ciuchi[2], and Giorgio Sangiovanni[1] — [1]Institut fuer Theoretische Physik und Astrophysik, Universitaet Wuerzburg, Germany — [2]Department of Physical and Chemical Sciences, University of L'Aquila, Italy

Particles without a high-energy analog, namely special multiple-degeneracy points in the electronic bandstructure of solids protected by fundamental symmetries of the underlying lattice, have been recently postulated in condensed matter physics [1]. A particularly interesting example is that of space groups Nr. 130 and 135, whose Brillouin zones host double Dirac points at high-symmetry points [2]. We study tight-binding models for these two space groups and look at the influence of electronic correlation on the eightfold degeneracies at the touching points of their valence and conduction bands. To this aim, we use methods ranging from simple approaches like the Hubbard-I and Hubbard-III approximations, to more sophisticated ones including DMFT and cluster extensions thereof [3].

[1] B. Bradlyn, et al., Science 353, aaf5037 (2016)
[2] B. Wieder, et al., PRL 116, 186402 (2016)
[3] D. Di Sante, et al., PRB 96, 121106(R) (2017)

TT 18.4 Mon 15:00 Poster D

Bychkov-Rashba Spin-Orbit Coupling Effects in a Multi-Band Tight-Binding Model of Graphene — •Thorben Schmirander, Marta Prada, and Daniela Pfannkuche — I. Institut für theoretische Physik - Universität Hamburg, Hamburg, Deutschland

The description of Dirac electrons in the band structure of graphene is commonly performed using effective tight binding models [1]. These effective models use single-orbital Hamiltonians with modified hopping parameters in order to account for the influence of the higher energy orbitals in graphene. We go beyond such effective models by including d-orbitals in an atomistic tight-binding model. The inclusion of the Bychkov-Rashba spin-orbit coupling splits each of the two Dirac cones into four distinct ones [2]. When considering a finite graphene sample, edge states occur, which cross the band gap and connect the Dirac cones at the K and K' point. These edge states are the key to the topological properties of graphene. The crossing of the edge states under the influence of Bychkov-Rashba spin-orbit coupling is examined by computing the winding number around each of the cones.

[1] van Miert, G., Juricic, V. and Morais Smith, C. Phys. Rev. B 90, 195414 (2014)
[2] van Gelderen, R. and Morais Smith, C., Phys. Rev. B 81, 125435 (2010)

TT 18.5 Mon 15:00 Poster D

Surface currents in Weyl semimetal nanowires — •Patrick Grössing, Daniel Hernangómez-Pérez, and Ferdinand Evers — Institute of Theoretical Physics, Regensburg University, D-93053 Regensburg (Germany)

We investigate the transport properties of thin wires made of a Weyl semimetal within the framework of a tight-binding model. Our focus is on bias induced surface currents in materials where time-reversal symmetry is broken because of magnetisation [1, 2]. Depending on the crystallographic growth direction, the current flow exhibits different patterns; in particular, large transverse (wrapping) currents can be observed. We perform a careful finite size analysis that reveals,. e. g., the interplay between quantum size effects and the Fermi arcs, which are a hallmark of the topological nature of the material [3, 4].

[1] P. Baireuther et al., New J. Phys. 18, 045009 (2016)
[2] A. Igarashi et al., Phys. Rev. B 95, 195306 (2017)
[3] F. D. M. Haldane, arXiv:1401.0529 (2014)
[4] Y. Chen et al., Phys. Rev. B 88, 125110 (2013)

TT 18.6 Mon 15:00 Poster D

Anomaly transport ingraphene and Weyl semimetals — •Klaus Morawetz — Münster University of Applied Sciences,Stegerwaldstrasse 39, 48565 Steinfurt, Germany — International Institute of Physics- UFRN,Campus Universitário Lagoa nova,59078-970 Natal, Brazil

Based on the quantum kinetic equations for systems with SU(2) structure, regularization-free density and pseudospin currents are calculated in Graphene and Weyl-systems realized as the infinite-mass limit of electrons with quadratic dispersion and a proper spin-orbit coupling. Correspondingly the currents possess no quasiparticle part but only anomalous parts. The intraband and interband conductivities are discussed. The optical conductivity agrees well with the experimental values using screened impurity scattering and an effective Zeeman field. The universal value of Hall conductivity is shown to be modified due to the Zeeman field. The chiral anomalous terms are shown to be derivable from a conserving transport theory and their usually believed origin is questioned.

[1] arXiv:1809.01547, arXiv:1806.06214, Phys. Rev. B 94 (2016) 165415, Phys. Rev. B 92 (2015) 245425, errata: Phys. Rev. B 93 (2016) 239904(E), Phys. Rev. B 92 (2015) 245426

TT 18.7 Mon 15:00 Poster D

Edge currents as a probe of the strongly spin-polarized topological noncentrosymmetric superconductors — •M. Biderang[1,2], M.H. Zare[3], H. Yavari[2], P. Thalmeier[4], and A. Akbari[1,5] — [1]Asia Pacific Center for Theoretical Physics, POSTECH, Pohang, Korea — [2]Department of Physics, University of

Isfahan, Isfahan, Iran — [3]Department of Physics, Faculty of Science, Qom University of Technology, Qom, Iran — [4]Max Planck Institute for Chemical Physics of Solids, Dresden, Germany — [5]Department of Physics, POSTECH, Pohang, Korea

Recently the influence of antisymmetric spin-orbit coupling has been studied in novel topological superconductors such as half-Heusler compounds and artificial heterostructures. We investigate the effect of Rashba and/or Dresselhaus spin-orbit couplings on the band structure and topological properties of a two-dimensional noncentrosymmetric superconductor. For this goal, the topological helical edge modes are analyzed for different spin-orbit couplings as well as for several superconducting pairing symmetries. To explore the transport properties, we examine the response of the spin-polarized edge states to an exchange field in a superconductor-ferromagnet heterostructure. The broken chiral symmetry causes the unidirectional currents at opposite edges[1].

[1] M. Biderang et al., Phys. Rev. B 98, 014524 (2018)

TT 18.8 Mon 15:00 Poster D

Decoherence of Majorana edge modes under adiabatic drives — •Zihao Gao, Yuval Vinkler-Aviv, and Achim Rosch — Institute for Theoretical Physics, University of Cologne, D-50937 Cologne, Germany

We study how Majorana edge modes behave under adiabatic movement in the presence of disorder, interactions and thermal fluctuations. In a 1D Kitaev chain, zero-energy Majorana bound states are formed at the edges of the topological region. Such Majorana edge modes are robust due to protection by an energy gap and their spatial separation. Therefore they can effectively encode a qubit, and are believed to be useful for quantum computation. By controlling the chemical potential we have the ability to adiabatically move these Majorana edge modes. However, during this process, disorder, interactions and thermal fluctuations can be harmful to the fidelity of the Majorana qubit. We numerically calculate the time-evolution of a Majorana qubit in such a setup in order to measure the decoherence from different sources, applying approximations based on exploiting the adiabatic nature of the movement and the protection by the gap.

TT 18.9 Mon 15:00 Poster D

Anyonic statistics of quantum impurities in two dimensions — •Enderalp Yakaboylu and Mikhail Lemeshko — IST Austria (Institute of Science and Technology Austria)

We demonstrate that identical impurities immersed in a two-dimensional many-particle bath can be viewed as flux-tube-charged-particle composites described by fractional statistics. In particular, we find that the bath manifests itself as an external magnetic flux tube with respect to the impurities, and hence the time-reversal symmetry is broken for the effective Hamiltonian describing the impurities. The emerging flux tube acts as a statistical gauge field after a certain critical coupling. This critical coupling corresponds to the intersection point between the quasiparticle state and the phonon wing, where the angular momentum is transferred from the impurity to the bath. This amounts to a novel configuration with emerging anyons. The proposed setup paves the way to realizing anyons using electrons interacting with superfluid helium or lattice phonons, as well as using atomic impurities in ultracold gases [1].

[1] E. Yakaboylu and M. Lemeshko, Phys. Rev. B 98, 045402 (2018)

TT 18.10 Mon 15:00 Poster D

Truncation of lattice fractional quantum Hall Hamiltonians derived from CFT — •Srivatsa N. S[1], Dillip Nandy[2], and Anne E. B. Nielsen[3] — [1]MPIPKS, Dresden, Germany — [2]Aarhus University, Aarhus, Denmark — [3]MPIPKS, Dresden, Germany

Conformal field theory has recently been applied to derive few-body Hamiltonians whose ground states are lattice versions of fractional quantum Hall states. The exact lattice models involve interactions over long distances, which is difficult to realize in experiments. It seems, however, that such long-range interactions should not be necessary, as the correlations decay exponentially in the bulk. This poses the question, whether the Hamiltonians can be truncated to contain only local interactions without changing the physics of the ground state. Previous studies have in a couple of cases with particularly much symmetry obtained such local Hamiltonians by a combination of guesswork and numerical optimization. Here, we propose a different strategy to construct truncated Hamiltonians, which does not rely on optimization, and which can be applied independent of the choice of lattice. We test the approach on models with bosonic Laughlin-like ground states and find that the overlaps per site between the states constructed from conformal field theory and the ground states of the truncated models are higher than 0.98 for all the studied lattices.

TT 18.11 Mon 15:00 Poster D

Effects of topological line defects on two-dimensional electronic transport — •Nico Bassler and Kai Schmidt — Institut für Theoretische Physik I, Universität Erlangen-Nürnberg, Staudtstraße 7, 91058 Erlangen, Germany

We investigate the effect of topological line defects on the transport properties of two-dimensional electronic systems. Experimentally, this is mostly motivated by bilayer graphene which is known to host a superstructure of line defects separating AB- and BA-stacking domains. More concretely, we study microscopically specific arrangements of such line defects by calculating the conductance, local densities, and topological invariants using an effective one-particle description for bilayer graphene in a magnetic field. In addition, we compare our findings to the well-known Haldane model on the honeycomb lattice, which is exactly solvable in the absence of line defects and displays a topologically non-trivial band structure.

TT 18.12 Mon 15:00 Poster D

Robustness of Haah's code in a magnetic field — •Matthias Walther and Kai Phillip Schmidt — Institut für Theoretische Physik I FAU Erlangen-Nürnberg, Erlangen, Deutschland

Haah's cubic code is an exactly solvable three-dimensional quantum spin model realizing topological fracton order. It is a promising candidate for self correcting quantum memory due to its macroscopic energy barrier between different ground states. Here we analyse the quantum robustness of this topological fracton order in a homogeneous magnetic field at zero temperature. Technically, this is achieved by applying the method of perturbative continuous unitary transformations and a mean-field approach. In all cases studied, we find strong first-order phase transitions separating the topological fracton phase and the polarized phase.

TT 18.13 Mon 15:00 Poster D

Quantum phase transitions to topological Haldane phases in spin-one chains studied by linked-cluster expansions — •Patrick Adelhardt[1], Julian Gritsch[1], Marvin Hille[2], David Anselm Reiss[1], and Kai Phillip Schmidt[1] — [1]Institute for Theoretical Physics, FAU Erlangen-Nürnberg, Germany — [2]Lehrstuhl für Theoretische Physik 1, TU Dortmund, Germany

We use linked-cluster expansions to analyze the quantum phase transitions between symmetry-unbroken trivial and topological Haldane phases in two different spin-one chains. The first model is the spin-one Heisenberg chain in the presence of a single-ion anisotropy, while the second one is the dimerized spin-one Heisenberg chain. For both models, we determine the ground-state energy and the one-particle gap inside the nontopological phase as a high-order series using perturbative continuous unitary transformations. Extrapolations of the gap series are applied to locate the quantum critical point and to extract the associated critical exponent. We find that this approach works unsatisfactorily for the anisotropic chain, since the quality of the extrapolation appears insufficient due to the large correlation length exponent. In contrast, extrapolation schemes display very good convergence for the gap closing in the case of the dimerized spin-one Heisenberg chain.