TT 25: Poster Session: Topology

Time: Thursday 13:30–16:00 Location: P

TT 25.1 Thu 13:30 P

Boosting the surface conduction in a topological insulator — •Mathieu Taupin[1], Gaku Eguchi[1], Monika Budnovski[1], Andreas Steiger-Thirsfeld[2], Yukiaki Ichida[3], Kenta Kuroda[3,4], Shik Shin[3], Akio Kimura[4], and Silke Paschen[1] — [1]Institute of Solid State Physics, TU Wien, Austria — [2]USTEM, TU Wien, Austria — [3]ISSP, The University of Tokyo, Japan — [4]Graduate School of Advanced Science and Engineering, Hiroshima University, Japan

Despite the intense research on topological insulators, manipulating the surface states by the application of external stimuli is surprisingly only little explored. For instance, some topological insulators have been shown to have an anomalous response when exposed to light, i.e. slow with non-exponential behaviour. These results hint on the tunability of the Dirac states with illumination, but the lack of consensus of the microscopic mechanism impedes progress.

Our work provides an understanding of these effects. We demonstrate that under external excitation (such as thermal radiation, light illumination and current driving), excited electrons will migrate to the surface states and remain there "permanently" due to the intrinsic Schottky barrier and space-charge separation between the surface and bulk carriers. This leads to a significant boost of the surface conduction, even in a bulk sample, which can be adjusted with the amplitude of the external excitation. We find striking similarities between our results and previous spectroscopic studies and propose a common mechanism, which is in principle applicable in any topological insulators.

TT 25.2 Thu 13:30 P

Dirac-like particles in a box in shaped topological insulator nanowires — •Maximilian Fürst, Michael Barth, Cosimo Gorini, and Klaus Richter — Universität Regensburg

Topological insulator nanowires exhibit strong spin-orbit coupling with surface states which are well-protected against backscattering [1]. Due to their Dirac-like dispersion they are intersting materials for studying emergent relativistic effects in condensed matter. We show how TI nanowires can be used to generate Dirac-like particles in a box by exploiting geometrical properties of the wires and applying an external coaxial magnetic field. These quantized energy levels can be probed by conductance calculations. In order to do that, we employ the numerical Python package kwant [2] and implement a shaped 3D topological insulator nanowire with a 3D bulk model as well as an effective 2D surface model. Quantized and flux dependent conductance lines exhibit strong constraints on the physical state of the trapped electrons what makes a practical application as a magnetically tunable momentum filter possible.

[1] X.-L. Qi and S.-C. Zhang, Rev. Mod. Phys. 83, 1057 (2011)
[2] Ch. W. Groth et al., New J. Phys. 16, 063065 (2014)

TT 25.3 Thu 13:30 P

Anisotropic Nodal-Line-Derived Large Anomalous Hall Conductivity in ZrMnP and HfMnP — •Sukriti Singh, Jonathan Noky, Shaileyee Bhattacharya, Praveen Vir, Yan Sun, Nitesh Kumar, Claudia Felser, and Chandra Shekhar — Max Planck Institute for Chemical Physics of Solids, Dresden, Germany

The nontrivial band structure of semimetals has attracted substantial research attention in condensed matter physics and materials science in recent years owing to its intriguing physical properties. Within this class, a group of non-trivial materials known as nodal-line semimetals is particularly important. Nodal-line semimetals exhibit the potential effects of electronic correlation in nonmagnetic materials, whereas they enhance the contribution of the Berry curvature in magnetic materials, resulting in high anomalous Hall conductivity (AHC). In this study, two ferromagnetic compounds, namely ZrMnP and HfMnP, are selected, wherein the abundance of mirror planes in the crystal structure ensures gapped nodal lines at the Fermi energy. These nodal lines result in one of the largest AHC values of 2840 ohm-1cm-1, with a high anomalous Hall angle of 13.6% in these compounds. First-principles calculations provide a clear and detailed understanding of nodal line-enhanced AHC. Our finding suggests a guideline for searching large AHC compounds.

TT 25.4 Thu 13:30 P

Observation of symmetry-enforced topological nodal planes in CoSi — Nico Huber[1], •Kirill Alpin[2], Grace L. Causer[1], Lukas Worch[1], Andreas Bauer[1], Georg Benka[1], Moritz M. Hirschmann[2], Andreas P. Schnyder[2], Christian Pfleiderer[1,3,4], and Marc A. Wilde[1] — [1]Physik Department, Technische Universität München, Garching, Germany — [2]Max-Planck-Institute for Solid State Research, Stuttgart, Germany — [3]MCQST, Technische Universität München, Garching, Germany — [4]Centre for Quantum Engineering (ZQE), Technische Universität München, Garching, Germany

In this work, we present a complete topological classification of CoSi, whose bandstructure features a plethora of Weyl points, topologically charged multifold crossings, and symmetry-enforced nodal planes. The latter are forced to have nonzero charges in the presence of SOC, which we show both theoretically for a general case and computationally via DFT calculations for CoSi, using an adaptive mesh of Wilson loops. The total charge is found to be consistent with the fermion doubling theorem. Resulting topological protectorates, intersections of the Fermi surface with topological nodal planes, are detected via measurements of Shubnikov-de Haas oscillations.

TT 25.5 Thu 13:30 P

Kerr effect in tilted nodal loop semimetals — Johan Ekström[1], Eddwi H. Hasdeo[1,2], Maria Belén Farias[1], and •Thomas L. Schmidt[1] — [1]Department of Physics and Materials Science, University of Luxembourg, L-1511 Luxembourg — [2]Research Center for Physics, Indonesian Institute of Sciences, South Tangerang, Indonesia

We investigate the optical activity of tilted nodal loop semimetals. We calculate the full conductivity matrix for a band structure containing a nodal loop with possible tilt in the $x-y$ plane, which allows us to study the Kerr rotation and ellipticity both for a thin film and a bulk material. We find signatures in the Kerr signal that give direct information about the tilt velocity and direction, the radius of the nodal loop and the internal chemical potential of the system. These findings should serve as a guide to understanding optical measurements of nodal loop semimetals and as an additional tool to characterize them.

TT 25.6 Thu 13:30 P

Impurity-induced bound states and resonances in lattice Dirac-Weyl semimetals — •João P. Santos Pires[1], Bruno Amorim[2], and João M. Viana Parente Lopes[1] — [1]Centro de Física das Universidades do Minho e Porto, University of Porto, 4169-007 Porto, Portugal — [2]Centro de Física das Universidades do Minho e Porto, University of Minho, 4710-057 Braga, Portugal

The discovery of gapless 3D semimetals turned Dirac-Weyl electrons into a hot topic in condensed matter. The possibility of a putative impurity- or disorder-driven quantum phase transition that turns a semi-metallic phase (with vanishing DoS at the Fermi level) into a diffusive metallic phase have attracted particular interest. Despite the vast number of recent work addressing this problem, the picture remains unclear and seemingly dependent on the precise type of disorder considered.

In this work, we use a projected Green function method to study a four-band gapless Dirac Hamiltonian discretised in a simple cubic lattice, and in the presence of impurities composed of spherical clusters with on-site energy U. With this method, we evaluate the correction to the total and local density of states induced by the impurity. For cluster of radius larger than one lattice spacing, we found that eigenstates bound to the impurity cluster are formed, at fine-tuned values of U that depart from the predictions from the continuum theory. As this radius is increased, the lattice results progress towards the continuum theory predictions.

TT 25.7 Thu 13:30 P

Artificial event horizons in Weyl semimetal heterostructures and their non-equilibrium signatures — •Christophe De Beule[1], Solofo Groenendijk[1], Tobias Meng[2], and Thomas L. Schmidt[1] — [1]Department of Physics and Materials Science, University of Luxembourg, L-1511 Luxembourg, Luxembourg — [2]Institute for Theoretical Physics and Würzburg-Dresden Cluster of Excellence ct.qmat, Technische Universität Dresden, 01069 Dresden, Germany

We investigate transport in type-I/type-II Weyl semimetal heterostructures that realize effective black- or white-hole event horizons. We provide an exact solution to the scattering problem at normal incidence and low energies, both for a sharp and a slowly-varying Weyl cone tilt profile. In the latter case, we find two channels with transmission amplitudes analogue to those of Hawking radiation. Whereas the Hawking-like signatures of these two channels cancel in equilibrium, we demonstrate that one can favor the contribution of either channel using a non-equilibrium state, either by irradiating the type-II region or by coupling it to a magnetic lead. This in turn gives rise to a peak in the two-terminal differential conductance which can serve as an experimental indicator of the artificial event horizon.

TT 25.8 Thu 13:30 P

Crossed Andreev reflection in topological insulator nanowire T-junctions — •Jacob Fuchs[1], Michael Barth[1], Cosimo Gorini[1,2], Inanc Adagideli[3,4], and Klaus Richter[1] — [1]Institut für Theoretische Physik, Universität Regensburg, 93040 Regensburg, Germany — [2]Université Paris-Saclay, CEA, CNRS, SPEC, 91191, Gif-sur-Yvette, France — [3]Faculty of Engineering and Natural Sciences, Sabanci University, 34956 Orhanli-Tuzla, Turkey — [4]Faculty of Science and Technology and MESA+ Institute for Nanotechnology, University of Twente, 7500 AE Enschede, The Netherlands

We numerically study crossed Andreev reflection (CAR) in a topological insulator nanowire T-junction where one lead is proximitized by a superconductor. We find that CAR should be clearly observable in a wide parameter range, including perfect CAR in a somewhat more restricted range. Furthermore, it can be controlled by a magnetic field and is robust to disorder.

TT 25.9 Thu 13:30 P

Improving topological superconductivity in two- and three-dimensional Josephson junctions — •Aidan Wastiaux[1] and Falko Pientka[1,2] — [1]Max Planck Institute for the Physics of Complex Systems, Dresden — [2]Institute of Theoretical Physics, Goethe University, Frankfurt am Main

As opposed to the numerous theoretical developments in the field of topological heterostructures hosting robust quasiparticles, difficulties are piling up for experimentalists on their way to building realistic and tunable setups with usable topological states. We address this widespread issue in a specific platform involving a planar Josephson junction made of a semiconductor with strong spin-orbit coupling by proposing easy-to-reach regimes of parameters with enhanced stability of the Majorana end states. Moreover, the extension of those findings to a three-dimensional model provides henceforth a new flexible platform for realizing chiral Majorana edge states. Possible setups using Van der Waals heterostructures are suggested.

TT 25.10 Thu 13:30 P

Weyl systems: anomalous transport normally explained — •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

The anomalous term $\sim \vec{E}\vec{B}$ in the balance of the chiral density can be rewritten as quantum current in the classical balance of density. This term is derived from the quantum kinetic equations for systems with SU(2) structure within a completely conserving approach and it is suggested that the term is of kinetic origin instead of anomaly. 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. 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.

[1] Eur. Phys. J. B 92 (2019) 176
Phys. Lett. A 383 (2019) 1362
[2] Phys. Rev. B 94 (2016) 165415
[3] Phys. Rev. B 92 (2015) 245425
[4] errata: Phys. Rev. B93 (2016) 239904(E)
[5] Phys. Rev. B 92 (2015) 245426

TT 25.11 Thu 13:30 P

Current correlations of Cooper-pair tunneling into a quantum Hall system — Andreas Michelsen[1,2], Thomas Schmidt[1], and •Edvin Idrisov[1] — [1]Department of Physics and Materials Science, University of Luxembourg, L-1511 Luxembourg, Luxembourg — [2]SUPA, School of Physics and Astronomy, University of St Andrews, North Haugh, St Andrews KY16 9SS, United Kingdom

We study Cooper-pair transport through a quantum point contact between a superconductor and a quantum Hall edge state at integer and fractional filling factors. We calculate the tunneling current and its finite-frequency noise to the leading order in the tunneling amplitude for dc and ac bias voltage in the limit of low temperatures. At zero temperature and in the case of tunneling into a single edge channel both the conductance and differential shot noise vanish as a result of the Pauli exclusion principle. In contrast, in the presence of two edge channels, this Pauli blockade is softened and a nonzero conductance and shot noise are revealed.

TT 25.12 Thu 13:30 P

Universal Hall conductance scaling in non-Hermitian Chern insulators — •Solofo Groenendijk[1], Thomas Schmidt[1], and Tobias Meng[2] — [1]Department of Physics and Materials Science, University of Luxembourg, L-1511 Luxembourg, Luxembourg — [2]Institute for Theoretical Physics and Würzburg-Dresden Cluster of Excellence ct.qmat, Technische Universität Dresden, 01069 Dresden, Germany

We investigate the Hall conductance of a two-dimensional Chern insulator coupled to an environment causing gain and loss. Introducing a biorthogonal linear response theory, we show that sufficiently strong gain and loss lead to a characteristic nonanalytical contribution to the Hall conductance. Near its onset, this contribution exhibits a universal power law with a power 3/2 as a function of Dirac mass, chemical potential, and gain strength. Our results pave the way for the study of non-Hermitian topology in fermionic transport experiments.

TT 25.13 Thu 13:30 P

Origin of the quasi-quantized Hall effect in $ZrTe_5$ — •Stanislaw Galeski and Johannes Gooth — Max Planck Institute for Chemical Physics of Solids, Dresden, Germany

The quantum Hall effect (QHE) is traditionally considered to be a purely two-dimensional (2D) phenomenon. Recently, however, a three-dimensional (3D) version of the QHE was reported in the Dirac semimetal $ZrTe_5$. It was proposed to arise from a magnetic-field-driven Fermi surface instability, transforming the original 3D electron system into a stack of 2D sheets. Here, we report thermodynamic, spectroscopic, thermoelectric and charge transport measurements on such $ZrTe_5$ samples. The measured properties: magnetization, ultrasound propagation, scanning tunneling spectroscopy, and Raman spectroscopy, show no signatures of a Fermi surface instability, consistent with in-field single crystal X-ray diffraction. Instead, a direct comparison of the experimental data with linear response calculations based on an effective 3D Dirac Hamiltonian suggests that the quasi-quantization of the observed Hall response emerges from the interplay of the intrinsic properties of the $ZrTe_5$ electronic structure and its Dirac-type semi-metallic character.

TT 25.14 Thu 13:30 P

Generalized Chern numbers based on open system Green's functions — Maria Belén Farias, •Solofo Groenendijk, and Thomas Schmidt — Department of Physics and Materials Science, University of Luxembourg, L-1511 Luxembourg, Luxembourg

We present an alternative approach to studying topology in open quantum systems, relying directly on Green's functions and avoiding the need to construct an effective non-Hermitian (nH) Hamiltonian. We define an energy-dependent Chern number based on the eigenstates of the inverse Green's function matrix of the system which contains, within the self-energy, all the information about the influence of the environment, interactions, gain or losses. We explicitly calculate this topological invariant for a system consisting of a single 2D Dirac cone and find that it is half-integer quantized when certain assumptions about the self-energy are made. Away from these conditions, which cannot or are not usually considered within the formalism of nH Hamiltonians, we find that such a quantization is usually lost and the Chern number vanishes, and that in special cases, it can change to integer quantization.

TT 25.15 Thu 13:30 P

Geometrical Rabi oscillations in non-Abelian systems — •Hannes Weisbrich[1], Gianluca Rastelli[2], and Wolfgang Belzig[1] — [1]Universität Konstanz — [2]Universita di Trento

Topological phases of matter became a new standard to classify quantum systems in many cases, yet key quantities like the quantum geometric tensor providing local information about topological properties are still experimentally hard to access, especially in non-Abelian systems [1] when states are degenerate and the quantum geometric tensor has a non-Abelian form. We propose protocols to determine the quantum geometric tensor in non-Abelian quantum systems. We show theoretically that for a weak resonant driving of the local parameters the coherent Rabi oscillations and their frequencies are related to the non-Abelian quantum geometric tensor [2]. Our schemes suggest also a way to prepare eigenstates of the quantum metric, a task that is difficult otherwise in a degenerate subspace.

[1] H. Weisbrich, R. L. Klees, G. Rastellli, and W. Belzig, PRX Quantum 2, 010310 (2021)
[2] H. Weisbrich, G. Rastellli, and W. Belzig, arXiv:2105.02689 (2021); accepted in Phys. Rev. Research (2021)

TT 25.16 Thu 13:30 P

Non-Hermitian band topology from momentum-dependent relaxation in two dimensional metals with spiral magnetism — •Johannes Mitscherling and Walter Metzner — Max Planck Institute for Solid State Research, Stuttgart, Germany

We present the emergence of non-Hermitian band topology in a two dimensional metal with planar spiral magnetism due to a momentum-dependent relaxation rate. A sufficiently strong momentum dependence of the relaxation rate leads to exceptional points in the Brillouin zone, where the Hamiltonian is non-diagonalizable. The exceptional points appear in pairs with opposite topological charges and are connected by arc-shaped branch cuts. We show that exceptional points inside hole and electron pockets, which are generally present in a spiral magnetic state with a small magnetic gap, can cause a drastic change of the Fermi surface topology by merging those pockets at isolated points in the Brillouin zone. The spectral function observed in photoemission exhibits Fermi arcs. Its momentum dependence is smooth - despite of the non-analyticities in the complex quasiparticle band structure.

TT 25.17 Thu 13:30 P

On the origin of the corner modes of the breathing kagome lattice — •Miguel Angel Jimenez Herrera[1,2], María Blanco de Paz[2], Aitzol García Etxarri[2,3], and Dario Bercioux[2,3] — [1]Centro de Física de Materiales (CFM-MPC) Centro Mixto CSIC-UPV/EHU, 20018 Donostia-San Sebastián, Basque Country, Spain — [2]Donostia International Physics Center, 20018 Donostia-San Sebastián, Spain — [3]IKERBASQUE, Basque Foundation for Science, Euskadi Plaza, 5, 48009 Bilbao, Spain

Quantum simulating techniques conform a perfect laboratory to study low-dimensional systems, such as the Su-Schrieffer-Heeger model, in 1D, or the breathing kagome model, in 2D [1]. Here, we address the realization of latter model using the muffin tin method, a first-principles-like technique based on planar wave expansion of the Bloch wave function. We study the standard kagome model and the two breathing phases using topological and symmetry markers. We claim that such breathing phases are both atomic limits: one shows zero bulk polarization, while the other, also called obstructed atomic limit, displays a finite value. We have performed a topological quantum chemistry [2] analysis and we have obtained the same result, supporting our results.

[1] Kempkes *et al.*, Nat. Mater. **18**, 1292 (2019)
[2] Bradlyn *et al.*, Nature **547**, 298 (2017)

TT 25.18 Thu 13:30 P

Carrier transitions in gapped Dirac systems induced by strong light pulses — •Mario Ebner[1], Vanessa Junk[1], Cosimo Gorini[1,2], and Klaus Richter[1] — [1]Institut für Theoretische Physik, Universität Regensburg, Germany — [2]Université Paris-Saclay, CEA, CNRS, SPEC, 91191, Gif-sur-Yvette, France

In order to understand the interesting consequences of matter interacting with strong light pulses, such as higher harmonics generation, it is necessary to investigate how the light field influences the occupation of the energy bands in the system.

We theoretically study this redistribution of carriers in a Dirac system, such as graphene, in the presence of a mass gap. This is done in two ways: Firstly, we model the behaviour of electrons in the system by a wave packet propagating under the influence of the electric field pulse. Secondly, we want to emphasize another approach similar to [1], which essentially breaks down to solving the time-dependent Schrödinger equation for a single $\boldsymbol{k}$-mode. This gives a complementary view of the physical processes involved. In particular, we discuss the interplay between the motion in reciprocal space due to the electric field and the dipole matrix element between valence and conduction band which determines the observed populations.

As an outlook, we sketch how to deduce the resulting current which can be split in intra- and interband contributions and which can be used for computing higher harmonics spectra.

[1] S. A. O. Motlagh *et al*, J. Phys.: Condens. Matter **32**, 065305 (2020)