TT 15: Quantum Transport and Quantum Hall Effects I (joint session HL/TT)

Time: Monday 15:00–17:15 Location: POT 251

TT 15.1 Mon 15:00 POT 251

Local Chern patches and networks of chiral modes in quantum Hall phases with spatial magnetic field profiles. — •Suraj Hegde and Tobias Meng — Institute of Theoretical Physics and Wurzburg-Dresden Cluster of Excellence ct.qmat, Technische Universitat Dresden, 01069 Dresden, Germany.

Transport experiments on curved Hall bars show a variety of non-trivial transport signatures. Motivated by these experiments, we develop a model that accounts for various features in multi-terminal Hall bar measurements and perform numerical simulations using KWANT. We model the effect of curvature of the sample through spatial variation of the magnetic field profile and find that it results in patches of quantum Hall phases characterised by different local Chern markers. We find that most of the transverse and longitudinal transport can be understood in terms of local Chern patches and an intricate interplay of chiral modes at the interface of different patches. We also show that the spatial magnetic field textures could provide a novel platform to engineer lattices formed by networks of chiral modes.

TT 15.2 Mon 15:15 POT 251

Effect of the external fields in high Chern number quantum anomalous Hall insulators — •Yuriko Baba[1,2], Francisco Domínguez-Adame[1], and Rafael A. Molina-Ferández[2] — [1]GISC, Departamento de Física de Materiales, Universidad Complutense, E–28040 Madrid, Spain — [2]Instituto de Estructura de la Materia, IEM-CSIC, E–28006 Madrid, Spain

Multilayer structures consisting of alternating magnetic and undoped topological insulator layers have been proved so far to be a convenient platform for creating a quantum Anomalous Hall state with a high Chern number [1]. However, in previous proposals, the Chern number can only be tuned by varying the doping concentration or the width of the magnetic topological insulator TI layers. This restricts the applications of the dissipationless chiral edge currents in electronics, since the number of conducting channels remains fixed. In this work, we propose a way of varying the Chern number at will by means of an external electric field applied along the stacking direction. The electric field generates the hybridization of the inverted bands, generating new topological channels. In this way, the number of Chern states can be tuned externally in the sample, without the need of modifying the number and width of the layers or the doping level. We showed that this effect can be uncovered by the variation of the transverse conductance as a function of the electric field at constant injection energy at the Fermi level. [2]

[1] Zhao, Y. F. et al., Nature, 588 (2020) 419
[2] arXiv:2208.03585

TT 15.3 Mon 15:30 POT 251

Novel thermo-electric transport channel in the conformal limit of tilted Weyl semimetals — Thorvald Ballestad[1], Alberto Cortijo[2], Maria Vozmediano[3], and •Alireza Qaiumzadeh[1] — [1]Center for Quantum Spintronics, Norwegian University of Science and Technology, Trondheim, Norway — [2]Universidad Autonoma de Madrid, Madrid, Spain — [3]Instituto de Ciencia de Materiales de Madrid, CSIC, Madrid, Spain

Recently, a new contribution to the Nernst current was proposed in 3D Dirac and Weyl semimetals, originated from quantum conformal anomaly [1,2]. In the present study, we analyze the effect of the tilt on the transverse thermo-electric coefficient of Weyl semimetals in the conformal limit, i.e., zero temperature and zero chemical potential. Using the Kubo formalism, we find a non-monotonic behavior of the thermoelectric conductivity as a function of the tilt perpendicular to the magnetic field, and a linear behavior when the tilt is aligned to the magnetic field. An "axial Nernst" current is generated in inversion symmetric materials when the tilt vector has a projection in the direction of the magnetic field. This analysis will help in the design and interpretation of thermo-electric transport experiments in recently discovered topological quantum materials [3].

[1] M. N. Chernodub et al, Phys. Rev. Lett. 120, 206601 (2018). [2] V. Arjona et al, Phys. Rev. B 99, 235123 (2019). [3] T. M Ballestad, A. Cortijo, M. A. H. Vozmediano, A. Qaiumzadeh, arXiv:2209.14331 (2022).

TT 15.4 Mon 15:45 POT 251

Selective scattering between counter-propagating edge states in a topological insulator — •Meng Hao[1,2], Li-Xian Wang[1,2], Fabian Schmitt[1,2], Hartmut Buhmann[1,2], and Laurens W. Molenkamp[1,2] — [1]Institute for Topological Insulators, Würzburg, Germany — [2]Physikalisches Institut (EP III) Würzburg University, Würzburg, Germany

The quantum Hall state, known by its dissipationless nature, comprises chiral edge states in a two-dimensional electron gas (2DEG). In the ordinary quantum Hall effect, all edge states propagate in the same direction, populated equally. Thus, they are immune to inter-edge-state scattering. In contrast, counter-propagating edge states, populated unequally, are naturally sensitive to the scattering process. However, a realization of this scenario so far was only possible by stacked layers of high-mobility 2DEGs, e.g., quantum wells or graphene. Here we realize the counter-propagating edge states in a three-dimensional topological insulator controlled by top and bottom gates. Surprisingly, the counter-propagating edge states prove to scatter into each other selectively. Our first attempt shows that this inter-edge-state scattering occurs exclusively between Landau levels with the same Landau index. We further propose a cross bar equipped with split-gates to determine the selection rule of scattering and scattering parameters unambiguously. Following this proposal, we will show some preliminary results and report our experimental advances.

30 min. break

TT 15.5 Mon 16:30 POT 251

Edge modes, Hall conductivity and topological features of a dice lattice: Fate of flat bands under strain — •Sayan Mondal and Saurabh Basu — Indian Institute of Technology Guwahati

We study the topological properties of a dice lattice, which has three atoms per unit cell (A, B, and C). In addition, the bands are systematically deformed via the introduction of anisotropy among the nearest neighbour (NN) hoppings in two distinct ways. In the first case, we apply the uniaxial strain, which alters the NN hoppings (between the sublattices A-B and B-C) along the direction of applied strain. While in the second case, we selectively tune the NN hopping between A and B sublattices which may be achieved by a controlled chemical pressure. The first case yields the Chern insulating lobes in the phase diagram with $C = \pm 2$ till a certain critical anisotropy, where the spectral gap vanishes. The quantized plateau in the anomalous Hall conductivity and the pair of chiral edge modes at each edge of a ribbon support the obtained values of the Chern numbers. Whereas, the second case (selective strain) shows distorted flat band in the dispersion spectrum, which alters the gap-closing condition as compared to the case of uniaxial strain. Also, the Chern insulating lobes in the phase diagram and the Hall conductivity have distinct features compared to the case above. However, in both cases, topological phase transitions take place which is demonstrated via the Chern number changing discontinuously from ± 2 to zero across the gap-closing transitions.

TT 15.6 Mon 16:45 POT 251

Structure-imposed electronic topology in graphene nanoribbons — •Florian Arnold[1], Tsai-Jung Liu[1], Agnieszka Kuc[2], and Thomas Heine[1,2,3] — [1]Technische Universität Dresden, Dresden, Germany — [2]HZDR, Leipzig, Germany — [3]Yonsei University, Seoul, Republic of Korea

Zigzag graphene nanoribbons (ZGNR) can be transformed into new structure types by removing terminal carbon atoms in a regular pattern. When a single atom is removed on each zigzag edge so-called cove-edged ZGNR (ZGNR-C) are created, while removing multiple atoms results in gulf-edged ZGNR (ZGNR-G). In our seminal work, we demonstrated the direct structure-electronic structure relation based on the structural parameters that unambiguously characterize ZGNR-C. This allowed to create a scheme that classifies their electronic state, i.e., if they are metallic, topological insulators or trivial semiconductors, and to find an empirical formula for the band gap of the semiconducting ribbons. Since then, we were able to expand this description to ZGNR-G systems where the chemical space of possible structures increases further due to the variable size of the gulf edges. With this, we give guidance to realize new graphene nanoribbon heterojunctions hosting topological states and investigate the transport properties of exemplary systems.

TT 15.7 Mon 17:00 POT 251

Massive and topological surface states in strained HgTe and evidence for parity anomaly — •Wouter Beugeling[1,2], Lixian Wang[1,2], David M. Mahler[1,2], Valentin L. Müller[1,2], Ewelina M. Hankiewicz[3], Hartmut Buhmann[1,2], and Laurens W. Molenkamp[1,2] — [1]Institute for Topological Insulators, Würzburg, Germany — [2]Physikalisches Institut (EP III), Würzburg University, Würzburg, Germany — [3]Institute for Theoretical Physics and Astrophysics (TP IV), Würzburg University, Würzburg, Germany

The idea that band inversion in a narrow-gap material can lead to Dirac-type surface states was noted by Volkov and Pankratov in the 1980's. Only about two decades later, it was realized that the surface states of topological insulators are the gapless Dirac states predicted by them. The massive Volkov-Pankratov states received much less attention. They are pulled from the bulk in a sufficiently large electric field and are topologically trivial. Until recently, direct evidence in the form of transport measurements was elusive.

From our magneto-transport experiments on a three-dimensional topological insulator heterostructure (strained HgTe), we demonstrate the coexistence of massless and massive Volkov-Pankratov states. The well-developed Hall quantization in the n- and the p-type regime is due to the topological surface state and the massive Volkov-Pankratov states, respectively, as confirmed by k·p theory. In a second series of experiments, we find a remarkable re-entrant quantum Hall effect in the p-type regime, which we can trace to spectral asymmetry, a salient manifestation of parity anomaly in a solid-state system.