TT 59: Poster Session: Topology

Time: Thursday 15:00–18:00 Location: P2/OG4

TT 59.1 Thu 15:00 P2/OG4

Density-dependence of surface transport in tellurium-enriched nanograined bulk Bi_2Te_3 — •Sepideh Izadi[1], Ahana Bhattacharya[2], Sarah Salloum[3], Stephan Schulz[3], Martin Mittendorff[2], and Gabi Schierning[1] — [1]Bielefeld University, Department of Physics, 33615 Bielefeld, Germany — [2]University of Duisburg-Essen, Department of Physics, 47057 Duisburg, Germany — [3]University of Duisburg-Essen, Department of Chemistry, 45141 Essen, Germany

Three-dimensional topological insulators (3D TI) demonstrate conventional parabolic bulk bands together with protected Dirac surface states. Bi_2Te_3 material is considered as a well-known 3D TI model, however, due to its complicated defect chemistry, high number of charge carriers in the bulk dominate transport signal, even as nanograined structures. Herein we introduce Te-enriched Bi_2Te_3 nanoparticles synthesis as a method to control the bulk charge carrier density. Therewith, defects-free and stoichiometric Bi_2Te_3 nanoparticles with sizes between 4 and 40 nm are synthesized using ionic-liquid based approach. Grain boundaries along Bi_2Te_3 facets are investigated using high resolution transmission electron microscopy (HRTEM). The resulting nanoparticles were compacted into nanograined pellets of varying porosity, thereby emphasizing the surface transport contribution. The nanograined pellets were characterized by a combination of electrical transport together with THz time-domain reflectivity measurements. Using the Hikami-Larkin-Nagaoka (HLN) model, a characteristic coherence length of 200 nm that is considerably larger than nanograins diameter is reported.

TT 59.2 Thu 15:00 P2/OG4

Topological phases in $TaRhTe_4$: from monolayer to bulk — •Xiao Zhang — Leibniz Institute for Solid State and Material Research, Dresden, Germany

Topological phases are studied in different dimensional $TaRhTe_4$ using the method of density functional theory (DFT). We find that bulk $TaRhTe_4$ is a Weyl semimetal, whereas both monolayer and bilayer $TaRhTe_4$ display features of quantum spin Hall (QSH) insulator. A complete phase diagram linking monolayer, bilayer, and bulk $TaRhTe_4$ is obtained by varying intra- and inter-bilayer distance of the three-dimensional structure. It contains phases of Weyl semimetal, weak topological insulator, and normal insulator.

TT 59.3 Thu 15:00 P2/OG4

Quantum transport through resonant Dirac states in topological insulator nanowire constrictions — •Michael Barth[1], Maximilian Fürst[1], Cosimo Gorini[2], and Klaus Richter[1] — [1]Institute of Theoretical Physics, University of Regensburg, D-93040 Regensburg, Germany — [2]Université Paris-Saclay, CEA, CNRS, SPEC, 91191, Gif-sur-Yvette, France

Quantum transport in topological insulator (TI) nanowires is expected to be mediated by surface states which wrap phase coherently around the circumference [1]. The spectrum corresponds to a quantized and gapped Dirac cone, where the gap is present because of a Berry phase of π which arises due to spin-momentum locking. In this work, we numerically study transport in TI constrictions which are subjected to an axial magnetic field. More specifically, we consider a realistic junction of a narrow TI wire which is smoothly connected at its two ends to broad TI leads and calculate the transmission through the setup with respect to the Fermi energy and the magnetic field. The latter is tuned to close the Berry gap [2]. It turns out, that perpendicular field components in the constriction lead to the formation of magnetic barriers which result in resonant Dirac states. The proposed system can be used to spectroscopically study the Dirac spectrum with respect to its gate and flux dependence. Moreover, different transport regimes are identified, which depend on the length of the central wire segment.

[1] J. H. Bardarson, P. W. Brouwer, and J. E. Moore Phys. Rev. Lett. **105**, 156803 (2010)
[2] J. Ziegler et al., Phys. Rev. B **97**, 035157 (2018)

TT 59.4 Thu 15:00 P2/OG4

Topological insulator as barrier in Josephson junction — •Anton Montag, Alexander Ziesen, and Fabian Hassler — RWTH Aachen University, Aachen, Germany

We numerically study the behavior of a long Josephson junction in a superconductor-topological insulator-superconductor setup. An s-wave superconductor is deposited on the disordered surface of a three-dimensional topological insulator proximitizing the surface states on both sides of the junction. The normal region is probed by a local tunnelling contact. We simulate the tunnel spectrum at energies below the bulk gap of the topological insulator as a function of the phase difference of the superconducting order parameter across the junction. The low-energy spectrum can be divided into trivial Andreev bound states usually appearing at higher energies and chiral edge modes which become gapless at a phase difference of π. Since the latter are topologically protected, they are essentially not affected by symmetry preserving onsite potential disorder on the topological insulator surface. We show the simulated tunnel spectra for various disorder configurations and compare it to analytical calculations.

TT 59.5 Thu 15:00 P2/OG4

Towards the quantum anomalous Hall effect in magnetic topological insulator structures — •Justus Teller[1,2], Erik Zimmermann[1,2], Micheal Schleenvoigt[1,2], Gerrit Behner[1,2], Kristof Moors[1,2], Peter Schüffelgen[1,2], Gregor Mussler[1,2], Detlev Grützmacher[1,2], and Thomas Schäpers[1,2] — [1]Peter Grünberg Institut (PGI-9), Forschungszentrum Jülich, D-52425 Jülich, Germany — [2]JARA-Fundamentals of Future Information Technology, Jülich-Aachen Research Alliance, Forschungszentrum Jülich and RWTH Aachen University, Germany

Three-dimensional topological insulators (TIs) are a material class which may enable robust topological quantum computing by using so-called Majorana zero modes. Published theoretical work predicts the Majorana state to exist in hybrid structures of superconductors and magnetic topological insulators which exhibit the quantum anomalous Hall effect (QAHE). We present magnetotransport measurements of Cr-doped magnetic $(Bi_{0.27}Sb_{0.73})_2Te_3$ layers. At 1.2 K, the uniformly Cr-doped samples exhibit a magnetic signature whose behaviour is probed under gate influence. Based on these measurements, an existing QAHE is ruled out. The results are compared to a magnetic TI heterostructure which is comprised of a plain TI layer embedded into two layers of magnetic TI. This structure reveals the QAHE. The temperature dependence of the effect is measured. In addition, the magnetic energy gap is probed by a gate dependent measurement. The QAHE is improved by current adjustment.

TT 59.6 Thu 15:00 P2/OG4

Axial topological insulator based DC SQUID in external SQUID layout — •Jan Karthein[1,3], Erik Zimmermann[1,3], Max Vassen Carl[1,3], Gerrit Behner[1,3], Abdur Rehman Jalil[1,3], Gregor Mussler[1,3], Peter Schüffelgen[1,3], Hans Lüth[1,3], Detlev Grützmacher[1,2,3], and Thomas Schäpers[1,3] — [1]Peter Grünberg Institut (PGI-9), Forschungszentrum Jülich, 52425 Jülich, Germany — [2]Peter Grünberg Institut (PGI-10), Forschungszentrum Jülich, 52425 Jülich, Germany — [3]JARA-Fundamentals of Future Information Technology, Jülich-Aachen Research Alliance, Forschungszentrum Jülich and RWTH Aachen University, 52425 Jülich, Germany

A three-dimensional topological insulator (TI) nanowire proximitized with a superconductor is predicted to be host to Majorana bound states that provide a platform for fault-tolerant quantum computation. Recently, axial TI-nanowire based DC SQUIDs showed coherent oscillations originating from the interference of topological surface states. We fabricate an axial TI-nanowire based DC SQUID with a neighboring Josephson junction completely in-situ, using selective-area growth and shadow mask fabrication techniques. An out-of-plane magnetic field is able to tune the flux inside the so formed external SQUID loop, while being decoupled from the in-plane magnetic field that tunes the flux inside the TI-nanowire. Coherent SQUID oscillations are visible when sweeping both the out-of-plane and in-plane magnetic field, proving that the axial TI-nanowire based DC SQUID and the external DC SQUID are experiencing phase-coherent transport.

TT 59.7 Thu 15:00 P2/OG4

Controlling the real-time dynamics of a spin coupled to the helical edge states of the Kane-Mele model — •Robin Quade[1] and Michael Potthoff[1,2] — [1]I. Institute of Theoretical Physics, Department of Physics, University of Hamburg, Notkestraße 9-11, 22607 Hamburg, Germany — [2]The Hamburg Centre for Ultrafast Imaging, Luruper Chaussee 149, 22761 Hamburg, Germany

The time-dependent state of a classical spin locally exchange coupled to an edge site of a Kane-Mele model in the topologically non-trivial phase is studied numerically by solving the full set of coupled microscopic equations of motion for the spin and the electron system. Dynamics in the long-time limit is accessible thanks to dissipative boundary conditions, applied to all but the zigzag edge of interest. We study means to control the state of the spin via transport of a spin-polarization cloud through the helical edge states. The cloud is formed at a distant edge site using a local magnetic field to inject an electron spin density and released by suddenly switching off the injection field. This basic process, consisting of spin injection, propagation of the spin-polarization cloud, and scattering of the cloud from the classical spin, can be used to steer the spin state in a controlled way. We find that the effect of a single basic process can be reverted to a high degree with a subsequent process. Furthermore, we show that by concatenating several basic injection-propagation-scattering processes, the spin state can be switched completely and that a full reversal can be achieved.

TT 59.8 Thu 15:00 P2/OG4

Fermi-surface investigation of CaCdGe and CaCdSn — •B.V. Schwarze[1,2], F. Husstedt[1,2], M. Uhlarz[1], D. Kaczorowski[3], and J. Wosnitza[1,2] — [1]Hochfeld-Magnetlabor Dresden (HLD-EMFL) and Würzburg-Dresden Cluster of Excellence-ct.qmat, HZDR, Germany — [2]Institut für Festkörper- und Materialphysik, TU Dresden, Germany — [3]Institute of Low Temperature and Structure Research, Polish Academy of Sciences, Poland

CaCdSn and CaCdGe are nodal-line semimetal candidate materials. These materials have one-dimensional lines or loops of topologically protected band-touching nodes. They sparked interest, due to their unique response to high magnetic or electric fields, including giant linear magnetoresistance and high charge-carrier mobility. These properties make them candidates for future technological applications. Band-structure calculations [1, 2] show for both systems non-topological and topological valence bands with the nodal band crossings above the Fermi level. Previous measurements of the magnetoresistance provide some support for the topological nature of the materials. Here, we present our investigation of the Fermi surfaces of CaCdSn and CaCdGe by use of de Haas-van Alphen measurements and band-structure calculations. Our measurements reveal many quantum-oscillation frequencies, which are not predicted by calculations. This discrepancy calls the calculated band structures [1, 2] and, thus, the precise nature of the topology of these systems into question.

[1] A. Laha et al., Phys. Rev. B 102, 035164 (2020).
[2] E. Emmanouilidou et al., Phys. Rev. B 95, 245113 (2017).

TT 59.9 Thu 15:00 P2/OG4

Ultrasound propagation in candidate material for electron hydrodynamics, Weyl semimetal WTe_2 — •Rafal Wawrzynczak[1], Stanislaw Galeski[1,2], and Johannes Gooth[1,2] — [1]Max Planck Institute for Chemical Physics of Solids, Nöthnitzer Straße 40, 01187 Dresden, Germany — [2]Physikalisches Institut, Universität Bonn, Nussallee 12, D-53115 Bonn, Germany

Interactions between electrons might lead to the appearance of a regime where the dominating time-scale is defined by momentum-conserving processes. This is manifested by electron liquid exhibiting features characteristic for classical liquids, like Poiseuille flow, resulting in non-Ohmic, sample-width-dependent resistivity. This was recently observed in a two-dimensional metal $PdCoO_2$ and two Weyl semimetals. Neither of the observations was accounted for with complete microscopic description. For WTe_2 there was proposed a mechanism based on the electron-electron scattering process involving a virtual phonon.

Here we report results of ultrasound propagation study performed on WTe_2 Weyl semimetal. We have analyzed temperature and field dependence of propagation of longitudinal and two transverse modes of different polarization propagating along the a crystallographic directions. The data shows anomalous decrease in speed of the longitudinal mode below 10 K and non-monotonous T-dependence of its attenuation. Moreover, quantum oscillations observed in all six measured quantities reveal the details of coupling between measured phonon modes and different parts of systems Fermi surface.

TT 59.10 Thu 15:00 P2/OG4

Photo-thermal imaging of $ZrTe_5$ in the quasi-quantized Hall regime — •Erica Warth Pérez Arias[1], Rafal Wawrzyńczak[1], Stansilaw Galeski[1], Johannes Gooth[2], Claudia Felser[1], and Fabian Menges[1] — [1]Max Planck Institute for Chemical Physics of Solids, Germany — [2]University of Bonn, Germany

$ZrTe_5$ has recently gained attention due to various intriguing experimental observations including the chiral magnetic effect [1] and the quasi-quantized 3D quantum Hall effect [2]. However, it remains challenging to probe the characteristic features of gapless surface and edge states experimentally. Addressing this challenge, we devised an optoelectronic detection scheme based on cryogenic magneto-optical laser scanning microscopy. The technique relies on a global electrical read-out of locally-induced currents, and contrasts previous all-optical studies of photogalvanic effects. We characterized $ZrTe_5$ single crystals with this approach and visualized rich spatial patterns of photo-induced transport as function of temperature and magnetic field. Remarkably, current maps obtained in the quasi-quantized Hall regime display long-range photoresponse over mm-distances and oscillations in magnetic field, hinting towards charge movement of ambient carriers in the system [3] driven by the photo-thermal effect [4] and the external magnetic field.

[1] Q. Li et.al., Nat. Phys. 12, 550-554 (2016)
[2] S. Galeski et.al., Nat. Commun. 12, 3197 (2021)
[3] J. C. W. Song et.al., Phys. Rev. B 90, 075415 (2014)
[4] Y. Wang et.al., arXiv:2203.17176 [cond-mat.mtrl-sci] (2022)

TT 59.11 Thu 15:00 P2/OG4

Anomalous transverse transport and phase transitions in Weyl semimetals RAlSi (R = La, Ce) — •erjian cheng — Leibniz Institute for Solid State and Materials Research (IFW-Dresden), 01069 Dresden, Germany

The noncentrosymmetric RAlPn (R = rare earth elements, Pn = Si or Ge) with the space-inversion (SI) symmetry breaking and/or the time-reversal (TR) symmetry breaking host multiple types of Weyl fermions, providing a fertile platform for the exploration of novel topological matter states. In particular, when magnetic configuration couples with the electronic wavefunctions, exotic anomalous transverse transport phenomena emerge. Here, by resorting to electrical and thermoelectrical transport, we systematically studied the ferromagnetic CeAlSi and its nonmagnetic analog LaAlSi, revealing the anomalous Hall effect (AHE) and/or anomalous Nernst effect (ANE). In addition, for LaAlSi, quantum oscillations reveal five frequencies. Moreover, a temperature-induced Lifshitz transition is unveiled in LaAlSi. For CeAlSi, magnetism enhances the anomalous transverse transport, implying that magnetism tunes the positions of Weyl nodes. Besides, high-pressure electrical transport and X-ray diffraction (XRD) measurements were also implemented, demonstrating multiple phase transitions. These results indicate that LaAlSi and CeAlSi provide unique and tunable systems to explore exotic topological physics, and a potential paradise for an array of promising applications for spintronics.

TT 59.12 Thu 15:00 P2/OG4

Electronic structure of topological superconductor candidate Li_2Pd_3B — •Gabriele Domaine[1], Jonas A. Krieger[1], Wei Yao[1], Changjiang Yi[2], Claudia Felser[2], Stuart S. P. Parkin[1], and Niels B. M. Schröter[1] — [1]Max Planck Institute for Microstructure Physics, Halle, Germany — [2]Max Planck Institute for Chemical Physics of Solids, Dresden, Germany

Chiral crystals are known to host a number of exotic quasiparticles which carry large Chern numbers and, as they are unconstrained from the celebrated spin statistics connection, can exhibit a range of unconventional (effective) spins [1]. These include, for instance, spin 3/2 Rarita-Schwinger, Kramers-Weyl, spin-1 and multifold fermions, which can be considered a generalization of conventional Weyl-fermions [2]. Here we present our preliminary results for the first Angle-Resolved Photoemission Spectroscopy (ARPES) measurements of the chiral crystal Li_2Pd_3B which is expected to host an as-yet unobserved multifold topological superconducting phase of class DIII, which is time reversal invariant), even without odd parity paring [3]. The superconducting gap is expected to arise from the intraband coupling at time-reversal invariant momentum points leading to an unconventional multiband gap function and nodal rings [4].

[1] N. B. M. Schröter et al. Nat. Phys. 15, 759 (2019)
[2] B. Bradlyn et al., Science 353, 6299 (2016)
[3] Z. S. Gao et al., Quantum Front 1, 3 (2022)
[4] C. Lee et al., Phys. Rev. B 104, L241115 (2021)

TT 59.13 Thu 15:00 P2/OG4

Implementing superconductor/skyrmion-host heterostructures using exfoliated Fe_3GeTe_2 on NbN — •Maximilian Daschner[1,2], Thomas Reindl[2], Marion Hagel[2], Jürgen Weis[2], and Malte Grosche[1] — [1]Cavendish Laboratory, University of Cambridge, UK — [2]Max-Planck Institute for Solid State Research, Stuttgart, Germany

Experimental coupling of chiral magnetism and superconductivity through the proximity effect is a challenging and unexplored field that can lead to novel physics. Chiral magnets host topological excitations known as skyrmions that, when coupled to the vortices in a superconductor, are predicted to form Majorana fermions at its boundaries and vortex cores. The van-der-Waals material Fe_3GeTe_2 is known to host a skyrmion state over temperature and field ranges that depend on the sample thickness. We have exfoliated flakes of Fe_3GeTe_2 from a high quality crystal grown by vapour transport, deposited them on a NbN film and patterned electrical contacts using standard e-beam lithography techniques. The resulting Hall bar shaped nanodevices provide a convenient system for investigating skyrmion/superconductor interactions: Hall measurements above the superconducting transition temperature T_c3 in combination with magnetic force measurements survey the skyrmion state as a function of applied field, and measurements of the critical current density below T_c3 probe skyrmion-assisted vortex nucleation and pinning.

TT 59.14 Thu 15:00 P2/OG4

Pressure-dependent structural instabilities and transport phenomena in candidate topological semimetal $LaSb_2$ — •Theodore Weinberger, Christian de Podesta, Jiasheng Chen, Stephen Hodgson, and Malte Grosche — Cavendish Laboratory, University of Cambridge, Cambridge CB3 0HE, United Kingdom

At low temperatures, and in the presence of large magnetic fields, $LaSb_2$ exhibits large, linear, non-saturating magnetoresistance, defying Fermi liquid behaviour. This phenomenon is thought to be caused by the onset of charge density wave order (CDW) below a sharp, hysteretic anomaly seen in resistivity data at $\sim$ 355 K. This anomaly is rapidly pushed to lower temperatures under applied hydrostatic pressure, where above 6 kbar, it is fully suppressed. Surprisingly, the anomalous magnetoresistance persists to pressures beyond 20 kbar even after the suppression of the resistive anomaly. Hence, we suggest that the magnetoresistance is not driven by the onset of CDW order. Instead, we propose that the high temperature anomaly corresponds to a structural transition, similar to that seen in $CeSb_2$, which is supported by *ab initio* density functional theory calculations. Further, these calculations indicate that the Fermi surface of LaSb2 contains small pockets in both its high and low pressure structures. Small Fermi surface pockets suggest that $LaSb_2$'s band structure might feature topological, Dirac-like, cones which may explain the observed large, linear magnetoresistance.

TT 59.15 Thu 15:00 P2/OG4

2π domain walls for tunable Majorana devices — •Daniel Hauck[1], Stefan Rex[2,3], and Markus Garst[1] — [1]Karlsruhe Institute of Technology, Institute for Theoretical Solid State Physics, Wolfgang-Gaede-Str. 1, 76131 Karlsruhe — [2]Institute for Quantum Materials and Technologies, Karlsruhe Institute of Technology, 76021 Karlsruhe, Germany — [3]Institute for Theoretical Condensed Matter Physics, Karlsruhe Institute of Technology, 76131 Karlsruhe

Superconductor-magnet hybrid structures provide a platform for investigating topological phases with localized Majorana states. Such states have previously been predicted for elongated Skyrmions in the magnetic layer. Here we consider 2π domain walls that can be easily controlled experimentally. Depending on the boundary conditions, we demonstrate that localized Majorana states can be found at both ends of such walls. This establishes 2π domain walls as tunable elements for the realization of Majorana devices.

TT 59.16 Thu 15:00 P2/OG4

DMRG simulations of the one-dimensional anyon Hubbard model — •Yannick Werner, Maximilian Kiefer-Emmanouilidis, Pascal Jung, and Sebastian Eggert — Department of Physics, Technical University of Kaiserslautern, 67663 Kaiserslautern, Germany

The recent detection of anyons in setups of ultra-cold gases has further encouraged the in-depth studies of anyonic systems. Although the existence of conventional anyons is limited to two dimensions, a realization of fractional exchange statistics in a 1D system is possible which leads to a continuous interpolation between bosons and (pseudo-)fermions. In this poster we present the effects of perturbations i.e. local impurities, in a one-dimensional anyonic Hubbard model with onsite and nearest neighbor interactions on local densities, correlation functions and density transport. Here anyonic statistics are fulfilled by mapping bosonic operators via Jordan-Wigner-transformation, leading to a density dependent Peierl's phase in the hopping term. Additionally, in the case of small filling rates, we compute and analyze numerically the Luttinger parameter via Density Matrix Renormalization Group methods and compare it with analytical results.

TT 59.17 Thu 15:00 P2/OG4

Dynamical structure factor of an anyonic Luttinger liquid — •Pascal Jung, Martin Bonkhoff, Yannick Werner, and Sebastian Eggert — Department of Physics and Research Center Optimas, Technical University of Kaiserslautern, 67663 Kaiserslautern, Germany

Luttinger liquids are a powerful tool to describe the low-energy excitations of bosonic and fermionic systems in one spatial dimension. Anyonic systems, which allow a continuous transition between those two fundamental types of statistics, can be included in this framework by an additional coupling of the current and density excitations. This results into different velocities for the left and right movers, breaking the spatio-temporal symmetries.

To study the effects of this symmetry breaking on experimentally verifiable quantities, characteristic correlation functions are calculated. Using these, the dynamical structure factor for a finite system is determined. The broken symmetry leads here to a characteristic imbalance between left and right movers with typical power laws. Furthermore, the impact of local impurities is investigated using the perturbative renormalization group. These results are compared to numerical simulations obtained by the DMRG algorithm.

TT 59.18 Thu 15:00 P2/OG4

Quantum spin dynamics in the spin-chain compound Cu_2OH_3Br — •Anneke Reinold[1], Kirill Amelin[2], Zhiying Zhao[3], Changqing Zhu[1], Patrick Pilch[1], Hans Engelkamp[4], Toomas Rõõm[2], Urmas Nagel[2], and Zhe Wang[1] — [1]TU Dortmund University, Germany — [2]National Institute of Chemical Physics and Biophysics, Tallinn, Estonia — [3]Fujian Institute of Research on the Structure of Matter, Chinese Academy of Sciences, Fuzhou, China — [4]Radboud University, Nijmegen, The Netherlands

In low-dimensional quantum magnets, exotic spin phenomena can emerge due to strong spin fluctuations. Here we investigate spin dynamics of the quantum spin-chain compound Cu_2OH_3Br by high-resolution terahertz spectroscopy as a function of temperature and in high magnetic fields. Below the Néel temperature T_N=9.3 K, this compound exhibits a unique magnetic structure consisting of alternating ferromagnetic and antiferromagnetic spin-1/2-chains of Cu^{2+}-ions [1,2]. In this ordered phase we observed magnetic excitations, which are characteristic for this unique spin structure and consistent with results of inelastic neutron scattering [2]. Moreover, we are able to track these spin excitations in applied magnetic fields crossing field-induced phase transitions [1].

[1] Z. Y. Zhao *et al.*, J. Phys.: Condens. Matter **31**, 275801 (2019)
[2] H. Zhang *et al.*, Phys. Rev. Lett. **125**, 037204 (2020)