TT 65: Poster Session Topological Topics

Time: Thursday 15:00–19:00 Location: P2/EG

TT 65.1 Thu 15:00 P2/EG

Quasiparticle interference and spin texture in thin film topological insulator — •Alireza Akbari[1,2,3,4] and Peter Thalmeier[3] — [1]Max Planck POSTECH Center for Complex Phase Materials, POSTECH, Pohang 790-784, Korea — [2]Asia Pacific Center for Theoretical Physics, POSTECH, Pohang, Korea — [3]Max Planck Institute for Chemical Physics of Solids, Dresden, Germany — [4]Department of Physics, POSTECH, Pohang, Korea

The protected surface states of topological insulators (TI) form gapless Dirac cones corresponding non-degenerate eigenstates with helical spin polarization. The presence of a warping term deforms the isotropic cone of the most simple model into snowflake Fermi surfaces as in Bi_2Se_3 and Bi_2Te_3. Their features have been identified in STM quasiparticle interference (QPI) experiments on isolated surfaces. Here we investigate the QPI spectrum for the TI thin film geometry with a finite tunneling between the surface states. This leads to a dramatic change of spectrum due to gapping and a change in pseudo spin texture that should leave distinct signatures in the QPI pattern. We consider both normal and magnetic exchange scattering from the surface impurities and obtain the scattering t-matrix in Born approximation as well as the general closed solution. We show the expected systematic variation of QPI 'snowflake' features by varying film thickness and study in particular the influence on back scattering processes. We show that a closing of the gap at special thickness due nonmonotonic tunneling matrix element should be visible in QPI.

TT 65.2 Thu 15:00 P2/EG

Signature of Unconventional Topological Superconductivity in Magnetic Penetration Depth — •Mehdi Biderang[1] and Alireza Akbari[1,2] — [1]Asia Pacific Center for Theoretical Physics, POSTECH, Pohang, Korea — [2]Max Planck POSTECH Center for Complex Phase Materials, POSTECH, Pohang, Korea

We propose a theoretical microscopic formulation of magnetic penetration depth for unconventional superconductors, considering both London (with local effects) and Pippard (with nonlocal effects) types. We examine our calculations for a variety of systems, including Sr_2RuO_4 as an example of multi-orbital superconductors, heavy fermion systems such as noncentrosymmetric superconductor $CePt_3Si$ with potential topological phase, a chiral superconductor UPt_3 with nontrivial Fermi arc surface state, and $CeCoIn_5$ with trivial topology. We find that for the London type superconductors the penetration depth varies linearly in temperature, for topologically nontrivial systems and it can demonstrate a signature of nodes in the gap function. However, the non-local response results in significant deviations from the linear behavior into a power-law temperature dependence.

TT 65.3 Thu 15:00 P2/EG

The Meservey-Tedrow technique applied to surface states of topological insulators — •Matthias Götte and Thomas Dahm — Universität Bielefeld, Bielefeld, Germany

The spin polarization of topological surface states is commonly measured by spin and angle resolved photoemission spectroscopy (SARPES), however with some ambiguities. As the spin polarization can be an important quantity for the efficiency of topological insulator materials in spintronic applications, we theoretically investigate an alternative technique.

The so called Meservey-Tedrow technique is based on spin dependent tunneling from a superconducting electrode and is an established technique for measuring the polarization of ferromagnets. Here, we show that it can be adapted to topological insulators to determine the in-plane component of the surface state spin polarization as well as the spin-flip scattering rate of surface electrons.

TT 65.4 Thu 15:00 P2/EG

Ferromagnetic topological insulators used as magnetic field sensors — •Matthias Borcherding and Thomas Dahm — Universität Bielefeld, Bielefeld, Germany

We investigate numerically the possibility of using ferromagnetic topological insulators to measure small changes in magnetic fields. For that, we calculate the intrinsic part of both the anomalous Hall and the spin Hall conductivity. Both the anomalous Hall effect and topological insulators are connected to the Berry curvature. We use a model for a three dimensional topological insulator and an effective two dimensional model. The latter is obtained from the first by applying a symmetric confining potential. We demonstrate conditions under which the sensitivity of such sensors becomes strongly increased.

TT 65.5 Thu 15:00 P2/EG

Electrical transport properties of Vanadium doped $Bi_2Te_{2.4}Se_{0.6}$ — Christian Riha[1], Birkan Düzel[1], Karl Graser[1], Olivio Chiatti[1], Oliver Rader[2], Jaime Sánchez-Barriga[2], Oleg Tereshchenko[3], and •Saskia F. Fischer[1] — [1]Novel Materials Group, Humboldt-Universität zu Berlin, 10099 Berlin, Germany — [2]Helmholtz-Zentrum-Berlin für Materialien und Energie, 12489 Berlin, Germany — [3]Physics Department, Novosibirsk State University, 630090 Novosibirsk, Russia

Magnetic doping of topological insulators is predicted to break the time reversal symmetry of the edge states and to cause the opening of a gap in the Dirac cone. This enables the observation of a transition from weak anti-localization to weak localization, as well as the occurrence of the anomalous quantum Hall effect. In this work, we investigate the transport properties of Vanadium doped $Bi_2Te_{2.4}Se_{0.6}$ and measure the low-field magnetoresistance at temperatures down to $T = 0.3$ K. All the samples show weak anti-localization and a hysteresis at low temperatures, which depends on the sweep-rate of the applied magnetic field.

TT 65.6 Thu 15:00 P2/EG

Magnetotransport phenomena of the quaternary topological insulator $Bi_{1.5}Sb_{0.5}Te_{1.8}Se_{1.2}$ — •Erik Zimmermann, Michael Schleenvoigt, Jonas Kölzer, Daniel Rosenbach, Gregor Mussler, Peter Schüffelgen, Hans Lüth, Detlev Grützmacher, and Thomas Schäpers — Forschungszentrum Jülich GmbH

Three-dimensional topological insulators form a new material class which may enable topological quantum computing using robust Majorana states. The interest in ternary and quaternary topological insulators recently increases as the magnetotransport of binary topological insulators is dominated by contributions from the bulk due to intrinsic doping. By varying the stoichiometry, we aim to place the Fermi level into the band gap within the bulk and close to the Dirac point at the surface in order to enhance the contributions from the surface states. We present cryogenic magnetotransport measurements performed on a selective-area grown $Bi_{1.5}Sb_{0.5}Te_{1.8}Se_{1.2}$ nano-Hallbar, revealing pronounced universal conductance fluctuations caused by the surface states. Furthermore, a unique temperature dependence reinforces that the universal conductance fluctuations originate from two-dimensional transport.

TT 65.7 Thu 15:00 P2/EG

Mobility spectrum analysis on the topological insulator $BiSbTeSe_2$ — •Jimin Wang[1], Alexander Kurzendorfer[1], Lin Chen[1], Zhiwei Wang[2], Yoichi Ando[2], Yang Xu[3], Ireneusz Miotkowski[3], Yong P. Chen[3], and Dieter Weiss[1] — [1]Institute of Experimental and Applied Physics, University of Regensburg, 93040 Regensburg, Germany — [2]Physics Institute II, University of Cologne, Zülpicher Str. 77, 50937 Köln, Germany — [3]Department of Physics and Astronomy, Purdue University, West Lafayette, Indiana 47907, USA

We conducted mobility spectrum analysis on high quality 3D topological insulator $BiSbTeSe_2$ to extract mobility μ, and carrier density n. Top and bottom gates were applied to tune the carrier density independently on top and bottom surfaces. At 1.5 K, when the conduction is almost entirely dominated by the Dirac surface states, we always find two dominant conduction channels (top and bottom surfaces), with $\mu = 1000 - 3000\,\mathrm{cm^2/Vs}$, and n on the order of $10^{12}\,\mathrm{cm^{-2}}$. However, at sufficiently high temperature ($T = 85$ K), when the bulk contributes, a third channel opens ($\mu \sim 200\,\mathrm{cm^2/Vs}$, and $n \sim 10^{12}\,\mathrm{cm^{-2}}$). Our analysis shows the feasibility of the method, which is also promising for similar material systems.

TT 65.8 Thu 15:00 P2/EG

Electron spin resonance spectroscopy measurement of a magnetic topological insulator material $MnBi_4Te_7$ — •Kavita Mehlawat[1,3], Alexey Alfonsov[1,3], Anna Isaeva[1,2,3], Bernd

Buechner[1,2,3], and Vladislav Kataev[1,3] — [1]Institute for Solid State and Materials Research, Leibniz IFW Dresden, Dresden, Germany — [2]Faculty of Physics, Technische Universitaet Dresden, Dresden, Germany — [3]Wuerzburg-Dresden Cluster of Excellence ct.qmat

The van der Waals compound $MnBi_4Te_7$ belongs to the family of $(Bi_2Te_3)_n(MnBi_2Te_4)$, (n = 0, 1, 2) heterostructures and is the first example of a compound which features both, the intrinsic net magnetization and band inversion. Static magnetic susceptibility (χ) and magnetization (M) measurements as a function of the applied field (H) on $MnBi_4Te_7$ show an antiferromagnetic state at T_N = 13 K and a ferromagnetic-like hysteresis occurring upon cooling below 5 K [1]. We performed electron spin resonance (ESR) spectroscopy measurements to explore the dynamic magnetic properties of $MnBi_4Te_7$. From high-frequency ESR measurements, we obtain evidence that $MnBi_4Te_7$ is an easy-axis type ferromagnet and ferromagnetic spin correlations persist up to T = 30 K on the time scale of an ESR experiment (10^{-10} - 10^{-11} s).

[1] Raphael C. Vidal et. al, arXiv:1906.08394

TT 65.9 Thu 15:00 P2/EG

Controlling a band gap at the K-points in graphene — •Frederik Bartelmann, Daniela Pfannkuche, Marta Prada, and Alexander Chudnovskiy — Universität Hamburg

In a tight-binding description without spin orbit interaction (SOI), the valence and conduction band of graphene touch at the K-points of the Brillouin zone [1]. SOI creates a band gap proportional to the contribution of atomic d-orbitals to the band states [2-4]. This contribution can be influenced via electric interactions, and consequently can the size of the gap. The effect of time-periodic electric fields on a tight-binding model of graphene is studied numerically by Floquet formalism and analytically by perturbation theory, to determine a method of controlling the band gap.

[1] A. H. Castro Neto, F. Guinea, N. M. R. Peres, K. S. Novoselov, and A. K. Geim, Rev. Mod. Phys. 81, 109, 2009
[2] S. Konschuh, M. Gmitra, and J. Fabian, Phys. Rev. B, 2010
[3] J. Sichau, M. Prada, T. Anlauf, T. J. Lyon, B. Bosnjak, L. Tiemann, and R. H. Blick, Phys. Rev. Lett. 122, 046403, 2019
[4] C. L. Kane and E. J. Mele, Phys. Rev. Lett. 95, 226801, 2005

TT 65.10 Thu 15:00 P2/EG

Magnetoelectric screening at the interface of a topological insulator and a ferromagnetic insulator — •Marius Scholten[1], Ilya Eremin[2], Jeroen van den Brink[1,3], and Flavio S. Nogueira[1] — [1]Institute for Theoretical Solid State Physics, IFW Dresden, Helmholtzstr. 20, 01069 Dresden, Germany — [2]Institut für Theoretische Physik III, Ruhr-Universität Bochum, D-44780 Bochum, Germany — [3]Institute for Theoretical Physics, TU Dresden, 01069 Dresden, Germany

It is well known that a ferromagnetic insulator (FMI) proximate to the surface of a topological insulator (TI) gaps the Dirac fermions when the out-of-plane component of the magnetization at the interface is non-vanishing. Consequently, a Chern-Simons (CS) term is generated by fluctuations of the Dirac fermions at the TI surface. This CS term consists of a magnetoelectric (ME) coupling and an additional Berry phase for the interface magnetization. For nonzero chemical potential, integrating out the Dirac fermions also generates a Dzyaloshinskii-Moriya interaction (DMI) which stabilizes skyrmions at the TI-FMI interface. In this work we discuss the consequences of the interplay between the CS and DMI terms in the effective action for the electrical screening. We discuss how the ME coupling to the magnetization modifies the dielectric function as a function of temperature and how this may lead to anti-screening effects at the interface. The dependence of the dielectric constant on temperature follows from the behavior of the interfacial magnetic susceptibility, which due to the DMI term also features a momentum space instability at the Curie temperature.

TT 65.11 Thu 15:00 P2/EG

Dynamical density and spin response of Fermi arcs and their consequences for Weyl semimetals — •Sayandip Ghosh[1] and Carsten Timm[2] — [1]Istituto Italiano di Tecnologia, Graphene Labs, Via Morego 30, 16163 Genova, Italy — [2]Institute of Theoretical Physics, Technische Universität Dresden, 01062 Dresden, Germany

Weyl semimetals exhibit exotic Fermi-arc surface states, which strongly affect their electromagnetic properties. We derive analytical expressions for all components of the composite density-spin response tensor for the surfaces states of a minimal Weyl-semimetal model. Based on the results, we discuss the electromagnetic susceptibilities, the current response, and other physical effects arising from the density-spin response. We find a magnetoelectric effect caused solely by the Fermi arcs. We also discuss the effect of electron-electron interactions within the random phase approximation and investigate the dispersion of plasmon excitations formed by Fermi-arc states. Our work is useful for understanding the electromagnetic and optical properties of the Fermi arcs.

TT 65.12 Thu 15:00 P2/EG

Negative Longitudinal Magnetoconductance at Weak Fields in Weyl Semimetals — •Andy Knoll, Carsten Timm, and Tobias Meng — Institute of Theoretical Physics, Technische Universität Dresden, 01062 Dresden, Germany

Weyl semimetals are topological materials that provide a condensed-matter realization of the chiral anomaly. A positive longitudinal magnetoconductance quadratic in magnetic field has been promoted as a diagnostic for this anomaly. By solving the Boltzmann equation analytically, we show that the magnetoconductance can become negative in the experimentally relevant semiclassical regime of weak magnetic fields. This effect is due to the simultaneous presence of the Berry phase and the orbital magnetic moment of carriers and occurs for sufficiently strong intervalley scattering.

TT 65.13 Thu 15:00 P2/EG

de Haas–van Alphen measurements of CoSi — •B.V. Schwarze[1,2], J. Hornung[1,2], K. Manna[3], T. Förster[1], and J. Wosnitza[1,2] — [1]Hochfeld-Magnetlabor Dresden (HLD-EMFL), HZDR, Dresden, Germany — [2]Institut für Festkörper- und Materialphysik, TU Dresden, Germany — [3]Max-Planck-Institut für Chemische Physik fester Stoffe, Dresden, Germany

It is known from angle-resolved photoemission spectroscopy (ARPES) that CoSi hosts unconventional chiral fermions. It exhibits a topological threefold band-touching node with a Chern number of +2 at the Γ point and a topological fourfold band-touching node with a Chern number of -2 at the R point. These nodes are protected by crystal symmetries and connected by giant surface Fermi arcs. They generate spin-1 fermions and charge-2 double Weyl fermions, respectively. We performed de Haas-van Alphen (dHvA) measurements up to 18 T and down to 40 mK. The angular dependence of the fundamental dHvA frequencies as well as their effective masses are in good agreement with our density-functional-theory calculations, confirming the topologically non-trivial band structure. We also observed multiple magnetic-breakdown frequencies, providing further information on the topological phase shift.

TT 65.14 Thu 15:00 P2/EG

Investigation of quantum oscillations in the topological chiral semimetal CoSi — •Nico Huber, Grace Causer, Georg Benka, Lukas Worch, Laura Stapf, Andreas Bauer, Marc Wilde, and Christian Pfleiderer — Technical University of Munich, 85748 Garching, Germany

Chiral semimetals are predicted to host massless topological fermions that are distinct from Dirac and Weyl fermions. Ab initio density functional theory (DFT) suggests the existence of such fermions in the transition-metal silicide CoSi.[1] In turn, electron orbits with a chiral charge around the R point in the Brillouin zone were deduced from quantum oscillations in the thermoelectrical properties of this material.[2] We report the results of Shubnikov-de Haas and de Haas-van Alphen measurements of CoSi down to milli-Kelvin temperatures. Our data confirm the oscillation frequencies reported in Ref. [2]. In addition, we performed angle-resolved measurements to determine the influence of the crystallographic orientation on these oscillations. We compare our results with comprehensive DFT calculations.

[1] Peizhe Tang, Quan Zhou, and Shou-Cheng Zhang, Phys. Rev. Lett. **119**, 206402 (2017)
[2] Xu et al., Phys. Rev. B **100**, 045104 (2019)

TT 65.15 Thu 15:00 P2/EG

Mirror anomaly induced anomalous Hall effect in $ZrTe_5$ — •Yongjian Wang, Alexey Taskin, and Yoichi Ando — Institute of Physics II, University of Cologne, D-50937 Cologne, Germany

Dirac semimetals with band crossings (i.e., Dirac nodes) protected by combined inversion symmetry, time reversal symmetry and additional crystal symmetry attract lots of interest due to their interesting topological properties [1,2]. Besides chiral anomaly, a new topological phenomenon, mirror anomaly induced anomalous Hall effect was recently theoretically predicted in Dirac semimetals [3]. In a Dirac semimetal, when the Dirac nodes are at a time reversal invariant momentum, the anomalous Hall conductivity is predicted to exhibit a step-like change when the field is rotated.

$ZrTe_5$ is a Dirac semimetal with only one Dirac point at the Γ point when the temperature is close to the resistivity peak temperature T_P [4], which provides a good platform for observing the mirror-anomaly-induced anomalous Hall effect. We have grown $ZrTe_5$ single crystals with very low T_P and observed a clear anomalous Hall effect in these samples. We report the magnetic-field-orientation dependence of the anomalous Hall conductivity and discuss whether it is consistent with the theoretical prediction.

[1] S. M. Young, et al., Phys. Rev. Lett. 108.14: 140405 (2012)
[2] Z. J. Wang, et al., Phys. Rev. B 88.12: 125427 (2013).
[3] A. A. Burkov, Phys. Rev lett. 120.1: 016603 (2018).
[4] B. Xu, et al., Phys. Rev. lett. 121.18: 187401 (2018).

TT 65.16 Thu 15:00 P2/EG

Phase diagrams of topological superconductors — •Jannis Neuhaus-Steinmetz, Elena Vedmedenko, Thore Posske und Levente Rózsa — Department of Physics, University of Hamburg, Hamburg, Germany

Non-collinear spin structures interacting with s-wave superconductors are promising candidates for topological superconductivity and Majorana physics. We study the interplay between non-collinear magnetic states and superconductivity theoretically by means of tight-binding calculations in combination with Monte Carlo simulations within the Heisenberg model. We derive the parameters of the Heisenberg Hamiltonian by fitting the energy dispersion originating from tight-binding calculations. The resulting magnetic ground states and phase diagrams will be discussed.

TT 65.17 Thu 15:00 P2/EG

Majorana zero modes in skyrmion-vortex pairs — •Jonas Nothhelfer[1,2], Kjetil Hals[3], Matteo Rizzi[4,5], and Karin Everschor-Sitte[1] — [1]Institut für Physik, JGU Mainz — [2]MPGC Mainz — [3]University of Agder, Grimstad, Norway — [4]Institute of Complex Systems, Forschungszentrum Jülich — [5]Institute for Theoretical Physics, Universität zu Köln

Ferromagnet-superconductor heterostructures allow for composite topological excitations such as skyrmion-vortex pairs [1], which can support the occurrence of localized Majorana bound states [2,3]. The non-abelian exchange statistics of Majorana modes makes them promising candidates for topological quantum computation. Our goal is to controllably braid Majorana modes via manipulating the skyrmions in such ferromagnet-superconductor composite topological excitations. To this end, we model a magnetic skyrmion imprinted in the ferromagnet and a vortex in the superconductor. We solve the eigensystem of the superconductor in the Bogoliubov-de Gennes formalism self-consistently for the superconducting gap under the influence of the magnetic field generated by the magnetic thin film and spin-orbit coupling. As predicted by [1] we reproduce that composite topological excitations can emerge as pairs of superconducting vortices bound to magnetic skyrmions. Exploiting the finite binding energy, we expect that the Majorana zero modes can be efficiently braided via the skyrmions using spintronic techniques.

[1] Kjetil Hals et al., PRL 117, 017001 (2016)
[2] Jonas Nothhelfer, Master Thesis
[3] Stefan Rex et al., PRB 100, 064504 (2019)

TT 65.18 Thu 15:00 P2/EG

Signatures of the Majorana spin and nonlocality in the electrical transport through a Majorana - quantum dot hybrid system — •Alexander Schuray[1], Manuel Rammler[1], and Patrik Recher[1,2] — [1]Institute for Mathematical Physics, TU Braunschweig, D-38106 Braunschweig, Germany — [2]Laboratory for Emerging Nanometrology Braunschweig, D-38106 Braunschweig, Germany

We investigate the electronic transport properties of a Majorana bound state (MBS) system in which more than one MBS is coupled to a spinful normal conducting lead on one side and a quantum dot on the other side. We use the full counting statistics to show that the only process contributing to the current is Andreev reflection in up to two channels that can be attributed to the two spin channels in the lead. The coupled quantum dot leads to the emergence of Fano resonances and the symmetry properties of these give insight about the coupling strength to both MBSs. We support our findings using a numerical tight binding model of a spin orbit coupled nanowire in proximity to a superconductor with an applied Zeeman field and treat the quantum dot using a self consistent mean field theory for the Coulomb interaction on the quantum dot.

TT 65.19 Thu 15:00 P2/EG

Probing Majorana bound states with an optical quantum dot — •Lena Bittermann[1], Daniel Frombach[1], Christophe De Beule[1], and Patrik Recher[1,2] — [1]Institut für Mathematische Physik, Technische Universität Braunschweig, Braunschweig, Germany — [2]Laboratory for Emerging Nanometrology, Braunschweig, Germany

Majorana bound states (MBSs) arise at the ends of a semiconducting nanowire in proximity to a superconductor when a sufficiently strong magnetic field is applied. Ever since signatures of MBSs were discovered, there has been a lot of research exploring their properties. Nevertheless, their spin structure [1] has only recently attracted attention. By coupling a quantum dot to one of the ends of the wire [2], the spin and nonlocal properties can be investigated [3,4].

Here, we propose a setup where we use an optical quantum dot tunnel-coupled to the end of a Majorana nanowire and to a hole reservoir forming a pn-junction as a spectroscopic tool. First, we solve the low-energy model for the wire coupled to the quantum dot and calculate the corresponding transition rates for the creation of photons via optical recombination. Furthermore, we use a master equation formalism to obtain the steady-state occupation probabilities. By analyzing the resulting photon emission intensities, we can draw conclusions on the spin polarization and nonlocality of the MBSs.

[1] D. Sticlet, C. Bena and P. Simon, PRL 108, 096802 (2012)
[2] M. T. Deng et al., Science 354, 1557 (2016)
[3] A. Schuray, L. Weithofer and P. Recher, PRB 96, 085417 (2017)
[4] E. Prada, R. Aguado and P. San-Jose, PRB 96, 085418 (2017)

TT 65.20 Thu 15:00 P2/EG

Floquet-Majoranas in a Cooper Pair Box — •Anne Matthies and Achim Rosch — Universität zu Köln, Institut für Theoretische Physik

A topological superconductor in one dimension can host Majorana zero modes at its edge. By driving the system periodically, so-called π modes (also named Floquet-Majoranas) can arise. These are topologically protected modes with an energy at the quasi-energy π/T where T is the period of the drive. We consider the role of π modes in the presence of long-ranged Coulomb interactions. We study a Cooper pair box made of two Josephson coupled superconducting topological quantum wires. Time-dependent gate voltages periodically drive the system. We investigate how to obtain and control π modes and study their stability in the presence of interactions.

TT 65.21 Thu 15:00 P2/EG

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

In this project we study how Majorana edge modes behave under slow, quasi-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. By controlling the chemical potential we have the ability to adiabatically move these Majorana edge modes. During this process, we analyze the Majorana qubit's fidelity loss induced by disorder, interactions and thermal fluctuations. Furthermore, we numerically calculate the time-evolution of a Majorana qubit in such a setup in order to measure the decoherence from different sources.

TT 65.22 Thu 15:00 P2/EG

Disorder effects on the spectral gap of topological insulator based Majorana zero modes — •Alexander Ziesen and Fabian Hassler — RWTH Aachen University, Aachen, Germany

We consider a 3D topological insulator (TI) proximitized by an s-wave superconductor with a vortex. It is known that the vortex traps a single unpaired Majorana zero mode (MZM). We numerically investigate the disorder dependence of the in-gap states. In particular, we concentrate on onsite potential disorder effects on the spectral gap for a chemical potential both being close and far away from the Dirac point. A large gap is desirable for this MZM to potentially be used for quantum information applications. We also show that one can efficiently simulate the 2D surface transport of a 3D TI using a three dimensional tight binding model and that we can restrict ourselves to purely surface disorder to correctly model the vortex setup.

TT 65.23 Thu 15:00 P2/EG

Transport and scanning tunneling microscopy study on $EuMnBi_2$ — •Xinglu Que[1], Jan Bruin[1], Mohammad Pakdaman[1], Claus Mühle[1], Jürgen Nuss[1], Qingyu He[1], Lihui Zhou[1], and Hidenori Takagi[1,2,3] — [1]Max Planck Institute for Solid State Research, Stuttgart, Germany — [2]Institute for Functional Matter and Quantum Technologies, University of Stuttgart, Germany — [3]Department of Physics, University of Tokyo, Japan

The quantum Hall effect (QHE) has been a compelling topic in physics in which the interplay of correlation and topology plays a key role. Though it is usually exclusive to two-dimensional electron systems, multilayered form of QHE has been reported in 3D materials with the layered pnictide $EuMnBi_2$ being a notable example. In this system antiferromagnetically ordered Eu ions decouple the Bi square net layers which host Dirac fermions, exhibiting rich magnetic textures. By controlling the magnetic phase distinct electronic structures are accessible.

We report our investigation on $EuMnBi_2$ utilizing transport measurement and scanning tunneling microscope (STM). Quantized Hall signals in both electrical and thermal conductance are clearly observed, with charge and entropy carriers characterized by Wiedemann-Franz law in this QHE system. STM results reveal atomically resolved surface after low temperature cleavage, and local spectroscopy finds features derived from Bi which is in good agreement with band structure calculations.

TT 65.24 Thu 15:00 P2/EG

Conductance through a quantum-Hall-superconductor junction from a tunneling perspective — •Fernando Dominguez Tijero[1] and Ewelina Maria Hanckiewicz[2] — [1]Institute for Mathematical Physics, TU Braunschweig, D-38106 Braunschweig, Germany — [2]Institute for Theoretical Physics and Astrophysics and Würzburg-Dresden Cluster of Excellence ct.qmat,University of Würzburg, Am Hubland, 97074 Würzburg, Germany

Motivated by the increasing number of transport experiments between a quantum-Hall (QH) bar and a superconducting (S) contact [1-5], we have investigated the current and noise between these two different subsystems using a tunneling approximation. This perturbative approach allows to understand the transport mechanism in a clearer way than previous numerical results based on an extended BTK formalism [6]. In addition, it allows to derive analytical results for the conductance and makes it possible to extend the study to other scenarios, such as QH-S-QH or fractional QH-S.

[1] P. Rickhaus et al. Nanoletters 12 1942 (2012)
[2] F. Amet et al. Science 352 966 (2016)
3] G.-H. Lee, et al.Nat. Phys. 13 693 (2017)
[4] M. R. Sahu et al. Phys. Rev. Lett. 121 086809 (2018)
[5] A. Seredinski et al. Science Adv. (2019)
[6] Hope et al. Phys Rev. Lett. 84 1804 (2000)

TT 65.25 Thu 15:00 P2/EG

0-π transitions in Josephson junctions out of 3D topological insulator nanowires with parallel magnetic field — •Jacob Fuchs, Michael Barth, Raphael Kozlovsky, Cosimo Gorini, and Klaus Richter — Institut für Theoretische Physik, Universität Regensburg, Germany

Josephson junctions out of 3D topological insulators (TIs) are investigated and Andreev bound states and supercurrents are calculated. Upon adding a (orbital) parallel magnetic field, bands with opposite angular momenta are split (similar to a Zeemann field splitting of the spin states). Because the field is also present in the superconducting part of the wire, Andreev reflection is modified. This leads to an energy shift of the Andreev bound states which, in turn, induces interesting 0-π transitions.

TT 65.26 Thu 15:00 P2/EG

Tunneling spectroscopy of $Tl_2Mo_6Se_6$ nanowires — •Mengmeng Bai, Yongjian Wang, and Yoichi Ando — Physics Institute II, University of Cologne, 50937 Cologne, Germany

Quasi-one-dimensional $Tl_2Mo_6Se_6$ is predicted to be a topological superconductor [1]. It is known that a pair of Majorana fermions will be induced at the end of a one-dimensional topological superconductor nanowire. Here we report our tunneling spectroscopy experiments on superconducting $Tl_2Mo_6Se_6$ nanowires. The $Tl_2Mo_6Se_6$ nanowires were exfoliated from the fiberlike single crystals. After that, they were fabricated into devices and then measured at temperatures down to 10 mK. A thin layer of Al_2O_3 is grown as a tunnel barrier for tunneling spectroscopy study. The preliminary tunneling spectroscopy results show rich structures both in and out of the superconducting gap.

[1] S.-M. Huang, C.-H. Hsu, S.-Y. Xu, C.-C. Lee, S.-Y. Shiau, H. Lin, and A. Bansil, Phys. Rev. B 97, 014510 (2018).

TT 65.27 Thu 15:00 P2/EG

Three-dimensional quantum Hall effect and thermopower in $ZrTe_5$ — •Toni Ehmcke and Tobias Meng — Institute of Theoretical Physics, Technische Universität Dresden, 01069 Dresden, Germany

Motivated by recent, unpublished experiments, we model electric and thermoelectric transport coefficients in $ZrTe_5$, a promising candidate material to realize the three-dimensional analogue of the quantum Hall effect due to its weakly coupled layer structure. Using a low-energy continuum model, we apply linear response theory to investigate the magnetic-field dependence of the longitudinal and Hall conductivities as well as the thermoelectric Seebeck and Nernst coefficients. We compare the results for different experimentally relevant situations and find good agreement with the experimental data.

TT 65.28 Thu 15:00 P2/EG

Topological charge pumping under realistic conditions — •Eric Bertok[1], Andrew Hayward[1,2], and Fabian Heidrich-Meisner[1] — [1]Institut für Theoretische Physik, Göttingen — [2]Arnold-Sommerfeld Center for Theoretical Physics, Munich

Recent experiments with ultra-cold atomic gases have realized topological charge pumps [1,2]. Non-adiabatic effects due to finite pumping speeds have already been studied via a Floquet analysis in the periodic system [3], but the combined effect of an external harmonic trap, a finite particle number, and these non-adiabatic effects due to a finite pump speed has not been considered. In our work, the interplay between these realistic aspects are explored and an interpretation of the mechanisms for topological charge pumping in a trapped system is developed. The full time-dependent Schroedinger equation is solved by exact diagonalization for the non-interacting system, and the dependence of the quantized particle transport on the pumping frequency and the trap strength is identified. Breakdowns from exact quantization due to excitations to the higher band are observed and are found to be highly dependent on the pumping frequency, with deviations for slow pumping and special pumping frequencies appearing at intermediate pumping times at which the pumping breaks down entirely.

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[1] Lohse et al. *Nature Phys* **12**, 350-354 (2016)
[2] Nakajima et al. *Nature Phys* **12**, 296-300 (2016)
[3] Privitera et al. *Phys. Rev. Lett.* **120**, 106601 (2018)

TT 65.29 Thu 15:00 P2/EG

Effects of the classical analog of the spin Berry curvature in adiabatic spin dynamics — •Simon Michel and Michael Potthoff — I. Institute of Theoretical Physics, Department of Physics, Universität Hamburg

We study the real-time dynamics of interacting many-body models consisting of slow and fast degrees of freedom in the adiabatic (Born-Oppenheimer-like) limit where certain topological terms can emerge in the effective equations of motion. In particular, we consider systems of slow classical spins coupled to fast spin or electron degrees of freedom. Using a Lagrangian approach, the fast variables are eliminated via suitable constraints such that one is left with an effective slow spin dynamics. This can be highly anomalous as is known, e.g., for a single classical spin coupled to a fast conduction-electron system, where the spin Berry curvature can lead to a strongly renormalized precession frequency [1].

Here, we study one or more slow classical spins coupled to a fast classical spin system using analytical as well as numerical techniques. For a single slow spin, we recover the anomalous precession [1] found earlier, even quantitatively. However, in the effective equation of motion the (quantum) Berry curvature is replaced by a (classical) topological charge density, similar to a skyrmion density but for skymions living on a product of Bloch spheres rather than in Euclidean space. For two and more slow spins, the geometrical spin torques resulting from the topological charge density give rise to unconventional effective RKKY-type couplings and dynamics.

TT 65.30 Thu 15:00 P2/EG

Magnetic properties of spin chain materials $Cs_2Co(Cl/Br)_4$

— •Thomas Leich[1], Daniel Brüning[1], Ladislav Bohatý[2], Petra Bohatý[2], Oliver Breunig[1], and Thomas Lorenz[1] — [1]II. Physikalisches Institut, Universitat zu Köln — [2]Institut für Kristallographie, Universität zu Köln

Cs_2CoCl_4 has been identified as an effective spin-1/2 chain material with strong XY anisotropy [1]. Due to inter-chain coupling it shows long-range magnetic order below 0.23 K with complex phase diagrams up to magnetic fields of 2.5 T [2]. Here we present a study of the isostructural substitution series $Cs_2CoCl_{4-x}Br_x$. Cs_2CoBr_4 shows some similar phases, but they are more stable and extend to tempeatures up to 1.35 K and magnetic fields up to 4 T. Measuring specific heat, magnetocaloric effect, thermal expansion and magnetization at temperatures down to 250 mK, the magnetic order of the different phases is characterized, as the material shows strong magnetic field dependence of magnetization, entropy and magnetostriction coefficient. We present phase diagrams for different field directions and discuss the origin of the phases. The 1D spin-chain physics is partly covered by the 3D magnetic order, and an increased single-ion anisotropy of about 20 K is determined, compared to 13.9 K in Cs_2CoCl_4.

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[1] O. Breunig et al., PRL 111, 187202 (2013)
[2] O. Breunig et al., PRB 91, 024423 (2015)

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Interacting magnons in the easy-axis square-lattice XXZ model

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The easy-axis square-lattice XXZ-model interpolates between the Ising model and the isotropic Heisenberg model. The system displays always long-ranged Néel order. However, the elementary excitations, except for the SU(2) symmetric Heisenberg point, correspond to gapped magnons and the spectrum is known to possess multi-magnon bound states. We follow the the excitation spectrum from the Heisenberg to the Ising model in order to find possible connections between , e.g., the amplitude Higgs resonance and the long-lived two-magnon bound states known from the Ising limit. Technically, this is achieved by the method of non-perturbative continuous similarity transformations in momentum space, which has been proven to capture the physics quantitatively in the Heisenberg limit.

TT 65.32 Thu 15:00 P2/EG

Linked cluster expansions for non-Hermitian quantum spin systems

— •Lea Lenke and Kai Phillip Schmidt — Chair for Theoretical Physics I, FAU Erlangen-Nürnberg, Germany

In quantum mechanics, the standard axiom of Hermitian Hamiltonians can be replaced by the axiom of PT-symmetric Hamiltonians without automatically loosing the realness of the energy spectrum. The properties of PT-symmetric quantum mechanics is investigated by applying the formalism of linked cluster expansions to the exactly solvable Ising chain in a complex transverse magnetic field. In a next step the gained experience will be used to study topological phase transitions in Kitaev's toric code in a magnetic field.