HL 85: Topological Insulators III (joined session with TT)

Time: Friday 9:30–12:30 Location: POT 251

HL 85.1 Fri 9:30 POT 251

Time-dependent defects in photonic topological insulators — •Christina Jörg[1], Fabian Letscher[1,2], Michael Fleischhauer[1], and Georg von Freymann[1,3] — [1]Physics Department and Research Center OPTIMAS, University of Kaiserslautern, Germany — [2]Graduate School Materials Science in Mainz, Kaiserslautern, Germany — [3]Fraunhofer-Institute for Physical Measurement Techniques (IPM), Kaiserslautern, Germany

To model topological insulators by means of classical optics, we fabricate arrays of evanescently coupled waveguides. These waveguides are about 1 μm in diameter at an aspect ratio of 1:500, and helically curved. The inverse of the waveguide array is fabricated via direct laser writing in a negative-tone photoresist. Subsequently the sample is infiltrated with a material of higher refractive index, creating low-loss 3D waveguides. Arranging the waveguides on a honeycomb-lattice, a robust edge mode exists due to topological protection [1]. This means that light moves along the edge unidirectionally, and even walks around defects without backscattering. Here, we discuss defects with time-dependent coupling, i.e., one waveguide with a different helicity than the rest of the waveguides. We examine three kinds of time-dependent defects: a) a straight waveguide, b) a waveguide with opposite helicity, c) a waveguide with same helicity but shifted by half a helix pitch in the z-direction. In all three cases the edge mode moves along the edge regardless of the defect, going partially around the defect and partially through it.

[1] M. C. Rechtsman et al., Nature 496, 196-200 (2013).

HL 85.2 Fri 9:45 POT 251

Aharonov-Bohm-type oscillations in HgTe topological insulator nanowires — •Johannes Ziegler[1], Raphael Kozlovsky[2], Ming-Hao Liu[2], Dmitriy Kozlov[1,3,4], Hubert Maier[1], Ze Don Kvon[3,4], Nikolay Mikhailov[3], Sergey Dvoretsky[3], and Dieter Weiss[1] — [1]Institut für Experimentelle und Angewandte Physik, Universität Regensburg, Germany — [2]Institut für Theoretische Physik, Universität Regensburg, Germany — [3]A.V. Rzhanov Institue of Semiconductor Physics, Novosibirsk, Russia — [4]Novosibirsk State University, Russia

In topological insulator nanowires, the helical surface states form a conducting cylinder enclosing the bulk. These states give rise to Aharonov-Bohm-type oscillations when a magnetic field is applied along the wire axis [1]. These oscillations, periodic with the flux quantum Φ_0, are predicted to change their phase periodically as a function of the Fermi level E_f. We fabricate nanowires with typical cross sections of 80 x 150 nm using an optimized wet etching process to maintain the high mobility and mean free path. In our experiments, we found, as expected, h/e periodic oscillations as a function of magnetic flux Φ with alternating maxima and minima as a function of E_f for $\Phi/\Phi_0 = 1/2$ and $\Phi/\Phi_0 = 1$. We compare the resulting periodicity with a simple model and electrostatic simulations.

[1] J.H. Bardarson *et al.*, Phys. Rev. L **105**, 156803 (2010)

HL 85.3 Fri 10:00 POT 251

Correlation and current anomalies in helical quantum dots — •Christophe De Beule[1], Niccolò Traverso Ziani[2], Mohammad Zarenia[1], Bart Partoens[1], and Björn Trauzettel[2] — [1]Department of Physics, University of Antwerp, 2020 Antwerp, Belgium — [2]Institute of Theoretical Physics and Astrophysics, University of Würzburg, 97074 Würzburg, Germany

We investigate the ground-state properties of a quantum dot on the surface of a time-reversal invariant topological insulator. Confinement is realized by ferromagnetic barriers and Coulomb interaction is treated with exact diagonalization. The topological origin of the dot has several consequences: (i) spin polarization increases and the ground state exhibits quantum phase transitions as a function of interaction strength, (ii) the onset of Wigner correlations takes place mainly in one spin channel, and (iii) the ground state is characterized by a persistent current that changes direction as a function of the radius.

We also consider the effect of superconducting correlations on the properties of the quantum dot. This allows us to analyze the influence of perturbations that violate particle-number conservation on the formation of the Wigner molecule.

HL 85.4 Fri 10:15 POT 251

Double topological surface states in strained alpha-Sn — •Victor Rogalev[1], Tomáš Rauch[2], Markus Scholz[1], Felix Reis[1], Lenart Dudy[1], Andrzej Fleszar[3], Marius-Adrian Husanu[4], Vladimir Strocov[4], Jürgen Henk[2], Ingrid Mertig[2,5], Jörg Schäfer[1], and Ralph Claessen[1] — [1]Physikalisches Institut und Röntgen Center for Complex Materials Systems, Universität Würzburg, 97074 Würzburg, Germany — [2]Institute of Physics, Martin Luther University Halle-Wittenberg, 06099 Halle (Saale), Germany — [3]Institut für Theoretische Physik und Astronomie, Universität Würzburg, 97074 Würzburg, Germany — [4]Swiss Light Source, Paul Scherrer Institute, CH-5232 Villigen, Switzerland — [5]Max Planck Institute for Microstructure Physics, 06120 Halle (Saale), Germany

The low temperature phase of Sn, α-Sn, is a semimetal with two pairs of "inverted" bands and zero energy band gap, which can be increased by strain. Experimental works revealed so far only one topological surface state (TSS) that bridges one pair of inverted bands.

By means of a combined experimental and theoretical approach we show that the electronic structure of the compressively strained α-Sn (001) thin film hosts an additional TSS in the valence band due to the second band inversion. This sub-surface localized TSS is directly accessed by soft X-ray angle-resolved photoemission with high probing depth. The second TSS reveals a much stronger hybridization with bulk states, in contrast to the already known surface-localized TSS. We show that such difference is consistent with the analysis of orbital composition of bulk and surface states.

HL 85.5 Fri 10:30 POT 251

Stencil lithography of MBE grown superconductors on top of topological insulator thin films — •Michael Schleenvoigt, Peter Schüffelgen, Daniel Rosenbach, Tobias W. Schmitt, Martin Lanius, Benjamin Bennemann, Stefan Trellenkamp, Elmar Neumann, Gregor Mussler, Thomas Schäpers, and Detlev Grützmacher — Peter Grünberg Institute 9, Forschungszentrum Jülich & JARA-FIT, 52425 Jülich, Germany

A stack of the two binary 3D topological insulators Bi2Te3 (n-type doped) and Sb2Te3 (p-type) forms a PN-heterostructure. Growing those topological heterostructures by means of MBE offers the possibility to tune the Fermi level of the upper surface to the Dirac-point. To protect the delicate Dirac system from degradation and oxidation we cap our heterostructures with a thin Al layer, before taking the sample to ambient conditions. We further developed this process to allow for in-situ growth of two different Al layers, i.e. a thin 1-2 nm Al layer on the full wafer followed by a thick Al film on well-defined areas by means of stencil lithography. The thin Al layer will subsequently oxidize after exposure to air and protect the delicate topological surface, whereas the thick Al layer with spatial extent in the (sub-)micrometer range will serve as superconducting contacts. Superconductor-Topological Insulator-Superconductor junctions with lateral dimensions in the nm range have then been fabricated. Despite the in-situ deposition, transport measurements and transmission electron microscope analysis indicate a low transparency, due to an intermixed region at the interface between topological insulator thin film and metallic Al.

Coffee Break

HL 85.6 Fri 11:15 POT 251

Induced superconductivity in lateral topological Josephson junctions with $(Sb_{0.94}Bi_{0.06})_2Te_3$ interlayer — •Daniel Rosenbach[1], Peter Schüffelgen[1], Martin Lanius[1], Gregor Mussler[1], Stefan Trellenkamp[1], Martin P. Stehno[2], Alexander Brinkman[2], Detlev Grützmacher[1], and Thomas Schäpers[1] — [1]Peter Grünberg Institute 9, Forschungszentrum Jülich, 52425 Jülich, Germany — [2]MESA+ Institute for Nanotechnology, University of Twente, 7500 AE Enschede, The Netherlands

The long sought Majorana fermion is predicted to arise in superconducting systems with p-wave pair correlation symmetry. Induced superconductivity in topological insulator thin films is expected to show partly p-wave pairing, such that Majorana zero modes (MZM) are thought to exist at the interface with a conventional s-wave superconductor. A current carried by these zero modes is supposed to show a doubled periodicity in the current-phase relation, compared to con-

ventional modes.
Molecular beam grown topological insulator ternary alloy thin films, of given composition, with a thin aluminum-oxide capping layer, have been prepared with lateral niobium superconducting contacts. Junctions of various geometries have been measured at low temperatures. The response to an externally applied magnetic field and to a radio-frequency signal is strongly dependent on the current-phase relation of the conductive modes. Characterization therefore includes an analysis of various Fraunhofer diffraction pattern as well as Shapiro step measurements at different frequencies.

HL 85.7 Fri 11:30 POT 251

Nontrivial topological phases in quantum mechanical many-body systems with gain and loss effects — •Marcel Klett, Holger Cartarius, and Guenter Wunner — 1. Institut für Theoretische Physik, Universität Stuttgart, 70550 Stuttgart

Non-Hermitian $\mathcal{PT}$-symmetric potentials are capable of effectively describing quantum systems with balanced in- and outfluxes. They allow for the existence of a $\mathcal{PT}$-symmetric phase with purely real energy spectra of the non-Hermitian Hamiltonian. Recently a possible relation between the appearance of the $\mathcal{PT}$-symmetric phase and topologically nontrivial states were found in two studies of simple model systems. However, they came to opposite conclusions. In the Su-Schrieffer-Heeger (SSH) model [1] the topological phase has a major influence. As soon as topologically nontrivial states appear $\mathcal{PT}$ symmetry gets broken. This is in contrast to the non-Hermitian Kitaev model [2], in which $\mathcal{PT}$ symmetry breaking does not depend on the topological phase. Our work is based on including different non-Hermitian potentials in the SSH model as well as the Kitaev model. We perform exact calculations of the eigenvalues and the eigenstates, clarify the relation between $\mathcal{PT}$ symmetry and topological phases, and explain why opposite results were found in the above mentioned systems.
[1] Baogang Zhu et al., Phys. Rev. A **89**, 062102 (2014)*
[2] Xiaohui Wang et al., Phys. Rev. A **92**, 012116 (2015)

HL 85.8 Fri 11:45 POT 251

Probing topological edge states in HgTe-based quantum wells by terahertz photogalvanic spectroscopy — •Kathrin-Maria Dantscher[1], Dimitry A. Kozlov[2], Maria-Theresia Scherr[1], Sebastian Gebert[1], Jan Bärenfänger[1], Mikhail Durnev[3], Sergey A. Tarasenko[3], Vasily V. Bel'kov[3], Nikolay N. Mikhailov[2], Sergey A. Dovertsky[2], Ze Dong Kvon[2], Dieter Weiss[1], and Sergey D. Ganichev[1] — [1]Terahertz Center, University of Regensburg, Regensburg, Germany — [2]A.V. Rzhanov Institute of Semiconductor Physics, Novosibirsk 630090, Russia — [3]Ioffe Institute, St.Petersburg, Russia

We report on the observation of a chiral photogalvanic current excited by terahertz laser radiation in the edge channels of HgTe-based 2D topological insulators (TI). The direction of the edge photocurrent reverses by switching the radiation polarization from the right- to left-handed one and, for fixed helicity, has opposite direction for opposite edges. The chiral edge photocurrent is detected in a wide range of gate voltages and reverse the sign twice upon variation of the gate voltage. We show that the data reveal that in the TI-regime the photocurrent is caused by photoionization of helical edge electrons to the conduction band, discuss the microscopic model of this phenomena and present the developed microscopic theory.

HL 85.9 Fri 12:00 POT 251

Topological phase space study of a generalized Kane-Mele spin-orbit Hamiltonian — •Tobias Frank, Petra Högl, Martin Gmitra, Denis Kochan, and Jaroslav Fabian — Theoretische Physik, Universität Regensburg

We study a generalized Kane-Mele [1] graphene spin-orbit coupling Hamiltonian, that is able to describe hybrid systems like graphene on transition metal dichalcogenides [2] or graphene - metal interfaces [3] with broken inversion symmetry. We identify the topological phase space in terms of its Z_2 invariant by variation of spin-orbit coupling parameters. We as well analyze the bulk-edge correspondence in terms of zigzag and armchair ribbons. We find that spin-orbit coupling proximitized graphene can exhibit helical edge states at the zigzag boundary even if it is in the trivial topological phase.

This work is supported by the DFG GRK 1570, SFB 689, and European Union Seventh Framework Programme under Grant Agreement No. 604391 Graphene Flagship.

[1] C. L. Kane and E. J. Mele, PRL 95 226801 (2005)
[2] M. Gmitra, D. Kochan, P. Högl, and J. Fabian, PRB 93 155104 (2016)
[3] T. Frank, M. Gmitra, and J. Fabian, PRB 93 155142 (2016)

HL 85.10 Fri 12:15 POT 251

HgTe shells on CdTe nanowires — •Jan Hajer, Maximilian Kessel, Christoph Brüne, Hartmut Buhmann, and Laurens W. Molenkamp — Physikalisches Institut, EP3, Am Hubland, 97074 Würzburg

Topological insulator nanowires in proximity to a superconductor are in research focus of condensed matter physics. Hosting Dirac-like surface states with high spin-orbit coupling, they are a possible platform for p-wave superconductivity and Majorana bound states.

In our work we investigate low temperature charge transport in quasi one-dimensional HgTe. Vapor-liquid-solid grown CdTe nanowires of high crystal quality serve as a substrate for epitaxial HgTe overgrowth. The core-shell heterostructures show residual strain, expected to transform the semi-metallic HgTe shell to a quasi one-dimensional topological insulator. Charge transport with proximitized superconductors indicates a high interface quality giving rise to the observation of multiple Andreev reflections and an induced supercurrent.