DS 5: Transport: Topological Insulators 1 (joint session with DS, HL, MA, O)

Time: Monday 15:00–17:45 Location: A 053

Invited Talk DS 5.1 Mon 15:00 A 053

The Wires' Approach to Topological Insulators — •Yuval Oreg — Weizmann Institute of Science, Rehovot, Israel

We suggest a construction of a large class of topological states using an array of quantum wires. We will show how to construct a Chern insulator using an array of alternating wires that contain electrons and holes, correlated with an alternating magnetic field. A generalization to wires, with alternating spin-orbit couplings which give rise to integer and fractional (Abelian and non-Abelian) topological insulators, is then straightforward.

Following this construction we will discuss suggestions for two possible experiments which give rise to a fractional Josephson-effect and in addition a novel spin-resolved current correlation effect.

DS 5.2 Mon 15:30 A 053

Helical Majorana surface states of strongly disordered topological superconductors with time-reversal symmetry — •Raquel Queiroz and Andreas Schnyder — Max Planck Instutute for Solid State Research, Stuttgart, Germany

Noncentrosymmetric superconductors with strong spin-orbit coupling and the B phase of ^{3}He are possible realizations of topological superconductors with time-reversal symmetry. The nontrivial topology manifests itself at the material's surface in terms of linearly dispersive helical Majorana modes protected by symmetry from disorder weaker than the superconducting gap. Using extensive numerical simulations, we investigate the stability and properties of these Majorana states under strong surface disorder, which influences both bulk and surface states. A critical crossover from weak to strong disorder is observed in both two and three dimensions, through which an extended state exactly at zero energy always persists. The localization properties of the ingap states are studied through the distribution of the local density of states and level repulsion statistics.

DS 5.3 Mon 15:45 A 053

Intrinsic conduction through topological surface states of insulating Bi_2Te_3 epitaxial thin films — •Katharina Hoefer[1], Christoph Becker[1], Diana Rata[1], Jesse Swanson[1,2], Peter Thalmeier[1], and Liu Hao Tjeng[1] — [1]Max Planck Institute for Chemical Physics of Solids, Dresden — [2]University of British Columbia, Vancouver

Topological insulators represent a new state of matter that open up new opportunities to create unique quantum particles. Many exciting experiments have been proposed by theory, yet, the main obstacle for their execution is material quality and cleanliness of the experimental conditions. The presence of tiny amounts of defects in the bulk or contaminants at the surface already mask these phenomena.

We present the preparation, structural and spectroscopic characterisation of MBE-grown Bi_2Te_3 thin films that are insulating in the bulk. Moreover, temperature dependent four-point-probe resistivity measurements of the Dirac states on surfaces that are intrinsically clean were conducted. The total amount of surface charge carries is in the order of $10^{12}\,\mathrm{cm}^{-2}$ and mobilities up to $4600\,\mathrm{cm}^2/\mathrm{Vs}$ are observed.

Importantly, these results are achieved by carrying out the preparation and characterisation all in-situ under ultra-high-vacuum conditions [1].

[1] K. Hoefer et al. PNAS, 2014, 111(42), 14979-14984.

DS 5.4 Mon 16:00 A 053

Quantum interference of edge supercurrents in a two-dimensional topological insulator — •Grigory Tkachov, Pablo Burset, Björn Trauzettel, and Ewelina Hankiewicz — Würzburg University

Josephson weak links made of two-dimensional topological insulators (TIs) exhibit magnetic oscillations of the supercurrent that are reminiscent of those in superconducting quantum interference devices (SQUIDs). We propose a microscopic theory of such a TI SQUID effect [1]. The key ingredient of our model is the exact treatment of the influence of an external magnetic field on the edge supercurrents. We show that this influence has the form of a 1D Doppler effect that describes the flux-controlled interference of the edge currents with superimposed suppression of Andreev reflection. Both long and short junctions are discussed. In particular, for long junctions the theory shows a temperature-driven crossover from the normal Φ_0-periodic SQUID pattern to a $2\Phi_0$-quasiperiodic pattern consisting of a series of alternating even and odd peaks (where $\Phi_0 = ch/2e$ is the magnetic flux quantum). The predicted even-odd effect is the signature of gapless (protected) Andreev bound states with a sawtooth dependence on the magnetic flux. Our findings may shed some light on the recently observed even-odd interference pattern in InAs/GaSb-based TI Josephson junctions, suggesting new operation regimes for nano-SQUIDs.

[1] G. Tkachov, P. Burset, B. Trauzettel, and E. M. Hankiewicz, arXiv:1409.7301.

DS 5.5 Mon 16:15 A 053

Rashba spin-orbit coupling at the quantum spin Hall edge — •Florian Geissler, Francois Crepin, and Björn Trauzettel — Universität Würzburg, Institut für Theoretische Physik und Astrophysik, Germany

Not only since the discovery of the quantum spin Hall effect, and up to most recent questions in the context of topological insulating materials, transport through one-dimensional systems is a problem of great importance and interest. In a quantum spin Hall system, electron transport occurs in conducting edge channels, that are spin-filtered with respect to their direction of motion, and was shown to be topologically protected by time-reversal symmetry. We use the helical Luttinger liquid model to study transport in such systems, when the perfect conductance is perturbed. Particularly, we show that a potential source of backscattering is provided by the combination of a Rashba spin-orbit coupling (SOC) impurity and electron-electron interactions, even though time-reversal symmetry remains preserved. Based on both renormalization group and Keldysh calculations, the scaling of the conductance with the external bias is derived at zero temperature. Moreover, we illustrate, that such SOC-impurities may give rise to interesting effects when being present in an interface of a Luttinger liquid connected to a superconductor.

15 min. break.

DS 5.6 Mon 16:45 A 053

Coexisting edge states and gapless bulk in topological states of matter — Yuval Baum[1], •Thore Posske[2], Ion Cosma Fulga[1], Björn Trauzettel[2], and Ady Stern[1] — [1]Department of Condensed Matter Physics, Weizmann Institute of Science, Rehovot 76100, Israel — [2]Institut für Theoretische Physik und Astrophysik, Universität Würzburg, 97074 Würzburg, Germany

We consider two dimensional systems in which edge states coexist with a gapless bulk. Such systems may be constructed, for example, by coupling a gapped two dimensional state of matter that carries edge states to a gapless two dimensional system in which the spectrum is composed of a number of Dirac cones. We find that in the absence of disorder the edge states could be protected even when the two systems are coupled, due to momentum and energy conservation. We distinguish between weak and strong edge states by the level of their mixing with the bulk. In the presence of disorder, the edge states may be stabilized when the bulk is localized or destabilized when the bulk is metallic. We analyze the conditions under which these two cases occur. Finally, we propose a concrete physical realization for one of our models on the basis of bilayer Hg(Cd)Te quantum wells.

DS 5.7 Mon 17:00 A 053

Spin texture of generic helical edge states — •Alexia Rod[1], Thomas L. Schmidt[2], and Stephan Rachel[1] — [1]Institut für Theoretische Physik, TU Dresden, Germany — [2]Department of Physics, University of Basel, Switzerland

Edge states of time-reversal topological insulators can be described as helical Luttinger liquids. The generic helical liquid is the most general model of a time-reversal invariant helical liquid without axial spin symmetry. This symmetry is usually broken in experimental realizations, and it has been shown that its absence changes the transport properties significantly [1]. For a translation invariant system, the breaking of axial spin symmetry manifests itself in a momentum-dependent rotation of the spin quantization axis. Its manifestation in real space has remained, however, elusive so far.

Here we show that one can extract the rotation of spin quantization axis also in real space, e.g. for topological insulator disks with broken spin symmetry but also other geometries which are not rotationally invariant [2]. This suggests that the concept of a generic helical liquid is independent of the microscopic model and the considered geometry.

[1] T.L. Schmidt, S. Rachel, F. von Oppen, L. Glazman, Phys. Rev. Lett. 108, (2012).
[2] A. Rod, T.L. Schmidt, S. Rachel, manuscript in preparation.

DS 5.8 Mon 17:15 A 053

Manipulation of helical edge state transport by a quantum magnet — •Peter Silvestrov[1], Patrik Recher[1], and Piet Brouwer[2] — [1]Institute for Mathematical Physics, TU Braunschweig — [2]Dahlem Center for Complex Quantum Systems, FU Berlin

Application of a magnetic field is usually considered as a way to open the gap in the spectrum of helical edge states, leading to a blocking of the edge current. Nevertheless, it was shown recently that the current is fully transmitted through the gapped region in case of interaction with a quantum magnet[1]. Here we consider other interesting features of the helical edge state current interacting with the magnet. First, we notice that although the current is transmitted, all electrons with energies close to the Fermi energy are fully reflected. The actual current is carried by the electrons with energies below the gap and well below the Fermi energy. This suggests that the magnet while allowing passing the current, fully blocks the thermal transport thereby acting as a cooler for the injected electron beam. Our second setup consists of two helical edges covered by the same magnet. The current injected into one edge creates a non-equilibrium magnetization driving a current in the second edge. The current in the first edge is now half-reflected and half-transmitted by the magnet. However, the partial reflection of the current does not cause any shot noise.

[1] Q.Meng, S.Vishveshwara, T.L.Hughes, arXiv:1312.7303.

DS 5.9 Mon 17:30 A 053

Probing spin-polarized edge state superconductivity by Andreev reflection in in-plane magnetic fields — •Rolf W. Reinthaler, Grigory Tkachov, and Ewelina M. Hankiewicz — Faculty of Physics and Astrophysics, University of Würzburg, Würzburg, Germany

Finding signatures of unconventional superconductivity in Quantum Spin Hall systems is one of the challenges of solid state physics. Here we induce superconductivity in a 3D topological insulator thin film to cause the formation of helical edge states, which are protected against backscattering even in finite magnetic fields. Above a critical in-plane magnetic field, which is much smaller than the critical field of typical superconductors, the quasi-particle gap closes, giving rise to energy-dependent spin polarization. In this regime the spin-polarized edge state superconductivity can be detected by Andreev reflection. We propose measurement setups to experimentally observe the spin-dependent excess current and dI/dV characteristics.