DS 17: Transport: Topological Insulators 3 (joint session with DS, HL, MA, O)

Time: Tuesday 14:00–16:00 Location: H 0110

DS 17.1 Tue 14:00 H 0110

Helical Surface States In Strained HgTe — •Jan Boettcher and Ewelina M. Hankiewicz — Universität Würzburg, Faculty for Physics and Astronomy, TP IV

Strained HgTe is a 3D topological insulator with negligible bulk conductivity, where the transport is dominated by the surface states for a wide density range [1]. We analytically show the existence of a topologically protected surface state within the framework of a simplified 6x6 Kane Hamiltonian defined on the half-space. Strained HgTe is different from other 3D TIs due to an additional coupling of the surface states, forming between the light-hole and electron-like (S) bands, to the heavy-hole bands. This coupling causes an avoided crossing between these bands and, therefore, opens a large gap in the surface state spectrum by which the topological protection is not affected. Furthermore, we investigate the spin texture of the surface states. In the presence of an external magnetic field, we study the Landau level spectrum and discuss the experimental signatures which would be a consequence of our model.

We acknowledge grant HA 5893/4-1 within SPP 1666.

[1] Brüne et al., arXiv:1407.6537 (to be published in PRX 2014).

DS 17.2 Tue 14:15 H 0110

Trasport signatures of a Zeeman-split quantum dot coupled to a helical edge state — •Benedikt Probst[1], Pauli Virtanen[2], and Patrik Recher[1] — [1]Institut für Mathematische Physik, TU Braunschweig, 38106 Braunschweig, Germany — [2]O.V. Lounasmaa Laboratory, Aalto University School of Science, Finland

We investigate the transport signatures of a Zeeman-split quantum dot (QD) containing a single spin 1/2 weakly coupled to a helical Luttinger liquid (HLL) within a generalized master equation approach. The HLL induces a tunable magnetization direction on the QD controlled by an applied bias voltage when the quantization axes of the QD and the HLL are noncollinear. This tunability allows to extract characteristic signatures of a HLL and the spin dynamics of the QD via the backscattering conductance and the current noise.

DS 17.3 Tue 14:30 H 0110

Effects of random Rashba spin-orbit coupling and magnetic impurities on edge state transport in topological insulators — Lukas Kimme[1], •Bernd Rosenow[1], and Arne Brataas[2] — [1]Institut für Theoretische Physik, Universität Leipzig, D-04103, Leipzig, Germany — [2]Department of Physics, Norwegian University of Science and Technology, NO-7491 Trondheim, Norway

CdTe/HgTe quantum-wells that exceed a critical thickness host topologically protected edge states, which give rise to a quantized conductance. Despite the topolgical protection, experimentally a mean free path of a few microns is found [1]. The experimentally observed weak temperature dependence of the mean free path challenges proposed theoretical explanations, many of which predict power law behaviors. We here consider a model where edge electrons experience spatially random Rashba spin-orbit coupling, and are also coupled to a magnetic impurity. Using a rate equation model, we determine the steady state of the impurity spin in the finite bias regime, and compute both linear and nonlinear resistances. For a finite density of impurity spins, we obtain a weak temperature dependence of the mean free path, in agreement with experimental findings.

[1] M. König, S. Wiedmann, C. Brüne, A. Roth, H. Buhmann,
L. W. Molenkamp, X.-L. Qi, and S.-C. Zhang,
Science 318, 766 (2007).

DS 17.4 Tue 14:45 H 0110

Spin-based Mach-Zehnder interferometry in topological insulator p-n junctions — •Fernando de Juan[1,2], Roni Ilan[1], and Joel E. Moore[1] — [1]University of California, Berkeley — [2]Freie Universität Berlin

A p-n junction, an interface between two regions of a material populated with carriers of opposite charge, is a basic building block of solid state electronic devices. From the fundamental physics perspective, it often serves as a tool to reveal the unconventional transport behavior of novel materials. In this work, we show that a p-n junction made from a three dimensional topological insulator (3DTI) in a magnetic field realizes an electronic Mach-Zehnder interferometer with virtually perfect visibility. This is owed to the confinement of the topological Dirac fermion state to a closed two-dimensional surface, which offers the unprecedented possibility of utilizing external fields to design networks of chiral modes wrapping around the bulk in closed trajectories, without the need of complex constrictions or etching. Remarkably, this junction also acts as a spin filter, where the path of the particle is tied to the direction of spin propagation. It therefore constitutes a novel and highly tunable spintronic device where spin polarized input and output currents are naturally formed and could be accessed and manipulated separately.

DS 17.5 Tue 15:00 H 0110

Broken-gap topological insulators in magnetic fields — Rafał Skolasinski[1], Dimitry Pikulin[2], and •Michael Wimmer[1] — [1]Delft University of Technology, The Netherlands — [2]University of British Columbia, Canada

Two-dimensional topological insulators have helical edge channels protected by time-reversal symmetry, leading to a quantized conductance within the topological gap. A magnetic field breaks time-reversal symmetry, and thus is expected to break the quantization of conductance. Yet, recent experiments on topological insulators in broken-gap InAs/GaSb quantum wells have found very little dependence on magnetic field [1]. We discuss the effects of the orbital and the Zeeman part of the magnetic field on broken-gap quantum wells, and consider in which regime quantized conductance can be preserved.

[1] L. Du et al., arXiv:1306.1925

DS 17.6 Tue 15:15 H 0110

Cherenkov effect in topological insulators — •Sergey Smirnov — Institute for theoretical physics, Regensburg University, 93040 Regensburg, Germany

The Cherenkov radiation discovered experimentally by Cherenkov in optics of transparent media and theoretically explained later by Tamm and Frank reappears in solids where particles move faster than sound and, as a result, excite lattice vibrations or phonons. In both cases the photons or phonons are distributed within a forward cone centered around the momentum of the particle producing the Cherenkov light or sound.

Here we demonstrate that at high energies helical particles on surfaces of topological insulators excite anomalous Cherenkov sound outside the forward cone when the anisotropy of the surface states exceeds a critical value. The sound features many outstanding properties. In particular, at strong anisotropy it localizes into a few forward and backward beams propagating along specific directions [1].

At low energies we predict that an in-plane magnetic field applied to a surface of a topological insulator will asymmetrically reverse the Cherenkov sound. This asymmetric Cherenkov acoustic reverse may be of practical relevance in design of low energy electronic devices such as acoustic ratchets or, in general, in low power design of electronic circuits with an external control of the Cherenkov dissipation [2].

[1] S. Smirnov, Phys. Rev. B 88, 205301 (2013).
[2] S. Smirnov, Phys. Rev. B 90, 125305 (2014).

DS 17.7 Tue 15:30 H 0110

One-dimensional Dirac electrons on the surface of weak topological insulators — •Alexander Lau[1], Carmine Ortix[1], and Jeroen van den Brink[1,2] — [1]Institute for Theoretical Solid State Physics, IFW Dresden, Germany — [2]Department of Physics, TU Dresden, Germany

We show that a class of weak three-dimensional topological insulators feature one-dimensional Dirac electrons on their surfaces. Their hallmark is a line-like energy dispersion along certain directions of the surface Brillouin zone. Interestingly, these one-dimensional Dirac line degeneracies are topologically protected by a symmetry that we refer to as in-plane time-reversal invariance. As an example, we demonstrate how this invariance leads to Dirac lines in the surface spectrum of stacked Kane-Mele systems.

DS 17.8 Tue 15:45 H 0110

Fractional quantization of the topological charge pumped in a 1D superlattice — •Pasquale Marra[1], Roberta Citro[1,2], and Carmine Ortix[3] — [1]CNR-SPIN, I-84084 Fisciano (Salerno), Italy

— [2]Dipartimento di Fisica "E. R. Caianiello", Universitá di Salerno, I-84084 Fisciano (Salerno), Italy — [3]Institute for Theoretical Solid State Physics, IFW Dresden, D-01069 Dresden, Germany

A one-dimensional quantum charge pump transfers a quantized charge in each pumping cycle. This quantization is topologically robust being analogous to the quantum Hall effect. The charge transferred in a fraction of the pumping period is instead generally not quantized. We show, however, that with specific symmetries in parameter space the charge transferred at well-defined fractions of the pumping period is quantized as integer fractions of the Chern number. We illustrate in details this fractional quantization in a one-dimensional Harper-Hofstadter model for both periodic and open boundary conditions, and discuss its relevance for cold atomic gases in optical superlattices.

[1] arxiv:1408.4457 [cond-mat]