
We analyze spin-dependent thermoelectric transport of topological insulators based on (Hg,Cd)Te quantum wells using the non-equilibrium Green’s function technique within the Bernevig-Hughes-Zhang model. The motivation for our work is to generate spin currents in a medium with strong spin orbit coupling by a gradient of temperature in the absence of magnetic fields. Furthermore, we would like to better understand to what extent the thermoelectric coefficients probe spectral properties of such devices.

We investigate specifically the spin Nernst effect, a transverse spin current induced by a longitudinal temperature gradient, in a four-terminal setup. Interestingly, we predict a peak in the spin Nernst signal when the device is operated in the topologically non-trivial regime. This peak is directly related to the minigap formed by overlapping edge states from opposite boundaries of our device. Hence, the spin Nernst effect is a powerful experimental tool to analyze the size and the structure of the minigap. Additionally, we see that the spin Nernst effect is rather sensitive to details of the band structure. We discuss how this effect can be used to distinguish the topologically trivial from the non-trivial regime and why the energy dependence of transport is markedly resolved in the experimental signatures of the spin Nernst signal.

Quantum transport in nanostructures of Bi$_2$Se$_3$-topological insulator — Joseph Dufoeur, Romuald Géraud, Andreas Teichgräber, Silke Hampel, Stephan Neubaus, Barbara Eichler, Oliver G. Schmidt, and Bernd Büchner — Institute for Solid State Research - IFW Leibniz Institute, Helmholtzstr. 20, D-01069 Dresden, Germany — 2Institute for Integrative Nanosciences - IFW Leibniz Institute, Helmholtzstr. 20, D-01069 Dresden, Germany

Three-dimensional topological insulators belong to a new class of semiconductors with a large spin-orbit coupling which have spin-polarized Dirac fermions at their surface. In theory, these materials are insulating in the bulk, so that charge transport is only due to electronic surface states. In practice, the Fermi energy often stands above or below the bulk band gap, due to uncontrolled defects formed during the growth of single crystals, or of epitaxial thin films or nanostructures. This makes the electrical properties of topologically protected surface states difficult to measure, unless ultra-thin flakes of these materials are prepared.

To overcome this difficulty, we performed quantum transport measurement in ultra-thin Bi$_2$Se$_3$ flakes grown by CVD. We used e-beam lithography techniques to pattern Hall bars in the topological insulator. The measurements were done at low temperature and in an in-plane and perpendicular magnetic field up to 15 T.

Interaction and disorder effects in 3D topological insulator thin films — Elio Koening, Pavel Ostrovsky, Ivan Protopopov, Igor Gornyi, and Alexander Mirlin — 1Institut für Theorie der Kondensierten Materie Karlsruher Institut für Technologie Wolfgang-Gaede-Str. 1 D-76131 Karlsruhe — 2Institut für Nanotechnologie Herrmann-von-Helmholtz-Platz 1 76344 Eggenstein-Leopoldshafen

It has been recently predicted that Coulomb interaction drives a surface of a 3D topological insulator into a critical state. We employ the sigma-model formalism to investigate the effect of electron-electron interaction on the transport by surface states in topological insulator thin films. We take into account the interaction of electrons on different surfaces and also the top-bottom asymmetry of the film (different densities of states and strength of disorder on top/bottom surface). This asymmetry is naturally present in experiments where the electronic densities on the surfaces are controlled independently by means of electrostatic gates. The lack of symmetry between top and bottom surfaces is shown to have strong effect on the film conductivity. The interplay of weak antilocalization, Coulomb interaction within and between surfaces and topological protection leads to a rich flow diagram representing the low temperature behavior of the system. The connection with recent experiments on Bi$_2$Se$_3$ films is discussed.

Bloom–Zener Oscillations in Graphene and Topological Insulators — Viktor Kuechler, Ralf Kuhl, and Alexander Richter — Institut für Theoretische Physik, Universität Regensburg, Germany

Conventional free electrons in a superlattice subject to an accelerating drift potential feature a periodic motion known as Bloch oscillations. This physical phenomenon is enriched for topological insulators and graphene, since the electronic structure of those materials close to the Fermi energy is governed by a linear dispersion with a vanishing Fermi velocity.
A key recent advancement in condensed-matter physics is to study the interplay between nontrivial topology and electronic correlations. In 5d transition-metal oxides, both the spin-orbit interaction and the electron correlation emerge at comparable orders of magnitude. In these systems, a variety of specifically tailored crystal structures are available, enabling the design of robust topological insulators. In this work, we study theoretically a monolayer of the 5d-compound Na$_2$IrO$_3$, modeled by a Hubbard-type of Hamiltonian on a honeycomb lattice where the spin symmetry is not conserved. Based on a variational cluster approach (VCA), the zero temperature phase diagram is obtained. We can identify, through an increase of the Hubbard $U$, the transition from a quantum spin Hall insulator to either a spin liquid phase or an antiferromagnetic insulating phase, depending on the strength of the spin-orbit coupling. We illustrate the evolution of the quasiparticle spectral function for bulk and edge-states upon variation of system parameters.

15 min. break.

A quantum dot in a quantum spin Hall edge: Interaction effects — Caresten Timm — Technische Universität Dresden, Germany

The edge states of a quantum spin Hall system are topologically protected but can be gapped by a magnetic field. A quantum dot realized by tunneling barriers in a quantum spin Hall edge is proposed and transport through this device is analyzed. The analysis goes beyond linear response and incorporates electron-electron interaction in a combination of Green-function and master-equation approaches. A partial recurrence of non-interacting behavior is found for strong interactions. The possibility of controlling the magnetization of the edge by a locally applied gate voltage is proposed.

Inelastic electron backscattering in a generic helical edge channel — Thomas L. Schmidt$^1$, Stephan Rachel$^1$, Felix von Oppen$^3$, and Leonid I. Glazman$^1$ — Department of Physics, Yale University, 217 Prospect Street, New Haven, CT 06520, USA — Department of Physics, University of Basel, 4056 Basel, Switzerland — Dahlem Center for Complex Quantum Systems and Fachbereich Physik, Freie Universität Berlin, 14195 Berlin, Germany

We calculate the low-temperature conductance of a generic one-dimensional helical liquid which exists at the edge of a two-dimensional topological insulator (quantum spin Hall insulator). In a generic case, the $S_z$ spin-symmetry is absent, which opens a possibility of single-particle inelastic electron backscattering. We show that although time-reversal invariance is preserved, inelastic backscattering gives rise to a temperature-dependent deviation from the quantized conductance, $\delta G \propto T^4$. In addition, $G^2$ is sensitive to the position of the Fermi level in the gap of the insulator. We present an effective model for this type of helical liquid and determine its parameters explicitly from numerically solving of microscopic model for two-dimensional topological insulators in the presence of Rashba spin-orbit coupling.

Magnetococonductance of disordered HgTe strips — Sven Evers and Klaus Richter — Institut für Theoretische Physik, Universität Regensburg, 93040 Regensburg, Germany

Quantum wells of HgTe show the fascinating phenomenon of edge state transport which leads to a finite conductance in an energy window where the bulk material is insulating. This edge conductance exhibits special properties. One is, that it is expected to be stable against non-magnetic disorder because of a topological protection by time-reversal symmetry.

Inspired by this, we numerically investigate how the conductance of disordered HgTe strips of finite width changes under the application of a time-reversal symmetry breaking external magnetic field. We compare our results for different disorder models to experimental data. Additionally, we study how the so-called “topological Anderson insulator” phase of HgTe strips, i.e. the phenomenon that finite disorder drives the metallic system into a quantum spin hall state with quantized edge conductance, is affected by the application of an external magnetic field.