DS 11: Transport: Topological Insulators 2 (joint session with DS, HL, MA, O)

Time: Tuesday 9:30–13:00 Location: H 3005

DS 11.1 Tue 9:30 H 3005

How electron-electron interactions may lead to a spontaneous time reversal symmetry breaking in (fractional) topological insulators — •Tobias Meng[1,2] and Eran Sela[3] — [1]Institut für Theoretische Physik, Technische Universität Dresden, 01062 Dresden, Germany — [2]Department of Physics, University of Basel, Klingelbergstrasse 82, CH-4056 Basel, Switzerland — [3]Raymond and Beverly Sackler School of Physics and Astronomy, Tel-Aviv University, Tel Aviv, 69978, Israel

We analyze the consequences of strong electron-electron interactions in topological insulators. Naively, topological insulators can be thought of as two copies of quantum Hall states for spin up and spin down electrons at opposite magnetic field, hence maintaining time reversal symmetry. Using an extension of the coupled-wire construction of quantum Hall states to systems with zero magnetic field, we find that interactions between electrons of spin up and spin down can stabilize a large family of fractional topological phases with broken time reversal invariance. The latter is manifest by a spontaneous spin polarization, a finite Hall conductivity, or by both. This suggests the possibility that strongly correlated fractional topological insulators may be unstable to spontaneous symmetry breaking.

DS 11.2 Tue 9:45 H 3005

Emergence of surface conductivity at low temperatures in FeSi — •Michael Wagner, Ralf Korntner, Andreas Bauer, and Christian Pfleiderer — Physik-Department, Technische Universität München, D-85748 Garching, Germany

We report a comprehensive study of the influence of the sample quality on the Hall-conductivity in the correlated semiconductor FeSi. For our study three high-quality $Fe_{1+x}Si$ single crystals with slightly different Fe concentrations x were grown by optical float zoning under ultra-high vacuum compatible conditions. While the magnetic properties vary sensitively for the samples studied, the transport properties display several key features that are independent of the Fe concentration. As our main result we find, that the Hall-conductivity of FeSi can be described in terms of a Drude-model. For low temperatures a second transport channel emerges besides bulk conductivity, which can be assigned unambiguously to the sample surface. Remarkably, the mobility of this surface conduction is extraordinarily high as compared to similar effects in conventional semiconductors, being quantitatively consistent with topological insulators such as Bi_2Te_3 where they are viewed as the signature of topologically protected transport channels.

DS 11.3 Tue 10:00 H 3005

Spin transport in 3d-topological insulator nanostructures — •Matthias Stosiek, Sven Essert, Cosimo Gorini, and Klaus Richter — Institut für Theoretische Physik, Universität Regensburg, 93040 Regensburg, Germany

The spin-momentum locking for charge carriers on the surface of three-dimensional topological insulators holds promising prospects for spintronics applications. In this predominantly numerical study, we investigate the transport properties of nanostructures of 3d-TIs with ferromagnetic leads using model Hamiltonians. We also explore the influence of external electric and magnetic fields.

DS 11.4 Tue 10:15 H 3005

Tunnel Magnetoresistance scan of surface states of 3D topological insulators — •Sthitadhi Roy — Max-Planck-Institut für Physik komplexer Systeme, Dresden, Germany

The Fermi-surface of surface states of a 3D topological insulator (TI) has zero magnetization owing to time reversal symmetry, but an arbitrary segment of the full Fermi surface has a unique magnetic moment consistent with the type of spin-momentum locking. A three-terminal set up is proposed which directly couples to the magnetization of a chosen segment of a Fermi surface, hence leading to a finite tunnel magnetoresistance (TMR) response of the non-magnetic TI surface states, when coupled to spin polarized STM probe. This multi-terminal TMR reconstructs the in-plane momentum locked spin texture and also the out-of-plane spin polarization of hexagonally warped Fermi surfaces relevant for materials like Bi_2Te_3. This proposal is further extended to surfaces exposed by cleaving crystals at arbitrary angles to the crystal growth axis, and it shown that the TMR response not only probes and distinguishes these surfaces uniquely but the study of the spin textures for different surfaces put together acts like a hologram of the bulk band structure of the material.

DS 11.5 Tue 10:30 H 3005

Weak Antilocalization of 3DTI Surface States in the Presence of Spin-Orbit Impurities — •Pierre Adroguer[1], Weizhe Liu[2], Dimitrie Culcer[2] und Ewelina Hankiewicz[1] — [1]Institut füt Theoretische Physik und Astrophysik, Universität Würzburg, Deutschland — [2]School of Physics, The University of New South Wales, Sydney, Australia

The recent realization of three dimensional topological insulators (3DTIs) allows to probe the coherent transport of Dirac systems. In the presence of scalar disorder, weak antilocalization (WAL) is observed. However, TIs are materials where spin-orbit plays a crucial role, and the effect of spin-orbit impurities on coherent transport had not be studied yet.

In conventional electron gases where electrons have a parabolic dispersion, the concentration of spin-orbit impurities is of significative importance. Indeed, when the concentration of spin-orbit impurities is increased, the sign of the quantum correction to conductivity changes, going from weak localization to weak antilocalization (WAL).

In this work, we derive with the standard diagrammatic technique the quantum correction to conductivity when we add spin-orbit impurities to the diffusion of Dirac fermions in a disordered potential. We show that for every concentration of the spin-orbit impurities we remain in the symplectic class of WAL. We also derive the value of this quantum correction to conductivity in the presence of a transverse magnetic field, and we show that fits with the conventional theory have to be revisited in the view of our results.

DS 11.6 Tue 10:45 H 3005

SmO thin films: a flexible route to correlated flat bands with nontrivial topology — •Deepa Kasinathan[1], Klaus Koepernik[2], Liu Hao Tjeng[1], and Maurits Haverkort[1] — [1]Max-Planck-Institut für Chemische Physik fester Stoffe, Nöthnitzer Str. 40, 01187 Dresden, Germany — [2]IFW Dresden, P.O. Box 270116, D-01171 Dresden, Germany

Using density functional theory based calculations, we show that the correlated mixed-valent compound SmO is a 3D strongly topological semi-metal as a result of a $4f$-$5d$ band inversion at the X point. We also show that the topological non-triviality in SmO is very robust and prevails for a wide range of lattice parameters, making it an ideal candidate to investigate topological nontrivial correlated flat bands in thin-film form. Moreover, the electron filling is tunable by strain. In addition, we find conditions for which the inversion is of the $4f$-$6s$ type, making SmO to be a rather unique system. The similarities of the crystal symmetry and the lattice constant of SmO to the well studied ferromagnetic semiconductor EuO, makes SmO/EuO thin film interfaces an excellent contender towards realizing the quantum anomalous Hall effect in a strongly correlated electron system.

15 min. break.

Invited Talk DS 11.7 Tue 11:15 H 3005

Interacting Topological Insulators — •Stephan Rachel — Institut für Theoretische Physik, Technische Universität Dresden

The physics of electronic correlations in systems with topological band structures is a young and exciting field. In this talk, I will give an overview of the most relevant and interesting interaction effects in 2D and 3D topological insulators. Specifically, I will address the physics of the Kane-Mele-Hubbard model, the prototypical model of a correlated topological insulator, and its descendants in 2D as well as topological Mott insulators emerging in 3D topological band structures. Eventually, I will explain how strong interactions can affect the surface states of strong topological insulators and lead to even more exotic phases.

DS 11.8 Tue 11:45 H 3005

Interplay of topology and interactions in the quantum Hall regime of two-dimensional topological insulators — •Stefan Jürgens, Maxim Kharitonov, and Björn Trauzettel — Institute of Theoretical Physics and Astrophysics, University of Würzburg, D-97074 Würzburg, Germany

We study a class of two-dimensional topological insulators, in which the single-particle edge states are preserved in the presence of the magnetic field by a symmetry (e.g., crystalline) other than time-reversal. We focus on the vicinity of the crossing point between the zero-mode Landau levels. At half-filling, Coulomb interactions become particularly strong and lead to the formation of the quantum Hall "ferromagnetic" state with gapped charge excitations in the bulk. We identify the phases of this state that have gapped or gapless collective charge edge excitations and are characterized by the presence or absence of spontaneous symmetry breaking. The transitions between these phases can occur either continuously (via second order) or abruptly (via first order), depending on the parameters of the system. These transitions are accompanied by the corresponding behavior of the egde gap, which could be detected in transport measurements. Our findings provide an example of the interplay of topological and interaction-induced (spontaneous symmetry breaking) phenomena in the strong coupling regime.

DS 11.9 Tue 12:00 H 3005

Superconducting proximity effect in three-dimensional topological insulators in the presence of external magnetic fields — •Pablo Burset, Grigory Tkachov, Ewelina Hankiewicz, and Björn Trauzettel — Institute for Theoretical Physics and Astrophysics, University of Würzburg, D-97074 Würzburg, Germany

The proximity induced pair potential in a topological insulator-superconductor hybrid features an interesting superposition of conventional spin-singlet potential from the superconductor and spin-triplet pairing induced by the surface state of the topological insulator. We theoretically describe ballistic junctions between superconductors and topological insulators under external magnetic fields. We use Green functions techniques to calculate experimentally relevant transport signatures like normal-superconductor tunnel spectroscopy, local density of states, and Josephson current. Additionally, we consider the effect of both topological order and an external magnetic field in the superconducting correlations. We associate the unconventional transport signatures with the symmetry of the singlet and triplet components of the pair potential.

DS 11.10 Tue 12:15 H 3005

Non-universal conductance fluctuations in 3D topological insulator nanowires. — •Emmanouil Xypakis[1], Jens H Bardarson[1], Louis Veyrat[2], Joseph Dufouleur[2], and Romain Giraud[2] — [1]Max-Planck-Institut fuer Physik Komplexer Systeme, Noethnitzer Straße 38, D-01187 Dresden, Germany — [2]Leibniz Institute for Solid State and Materials Research, IFW Dresden, D-01069 Dresden, Germany

The topic of this talk is a joint theoretical and experimental study of conductance fluctuations in 3D strong topological insulator nanowires. Specifically, when a nanowire is subjected to a magnetic field and disorder weak enough to be away from the universal diffusive limit, the amplitude of the conductance fluctuations oscillates with respect to the magnetic field along the wire. We explain this oscillatory behaviour by the Dirac nature of the topologically protected surface quasiparticles of the topological insulator. We further demonstrate the robustness of this quasi-ballistic transport regime by a direct comparison with experimental data obtained for Bi_2Se_3 nanowires.

DS 11.11 Tue 12:30 H 3005

How dephasing and charge puddles affect the edge transport in 2d-topological insulators — •Sven Essert, Viktor Krueckl, and Klaus Richter — Institut für Theoretische Physik, Universität Regensburg, 93040 Regensburg, Germany

State of the art 2d-TI material systems show a length dependent non-quantized conductance for sample sizes larger than one micron. This feature is so far not well understood: Coherent elastic backscattering is symmetry forbidden and the observed weak temperature dependence does not seem to match the predictions for inelastic backscattering. We analytically and numerically investigate the effects of a third mechanism which was proposed to play a major role for the edge resistance: The combined effect of dephasing and elastic backscattering in charge puddles which are known to exist in the experimental samples.

We extract a range of dephasing times which are consistent with the experimental results. In addition, we make predictions for experiments on artificial charge puddles from which the real dephasing time scale could be determined.

DS 11.12 Tue 12:45 H 3005

Anderson localization at the edge of a 2D topological insulator — •Eslam Khalaf and Pavel Ostrovsky — Max Planck institute for solid state research, Stuttgart, Germany

We study transport via edge modes in a 2D topological insulator. Topological protection prevents complete localization of the edge states; however, quantum interference effects are still relevant for the transport properties at finite length scales. We mainly focus on the two most experimentally relevant cases: (i) a junction between two quantum Hall insulators with different filling factors and hence an imbalance in the number of right- and left-propagating modes (symmetry class A) and (ii) a relatively thick HgTe quantum well in the insulating state with an arbitrary number of edge modes (symmetry class AII). We derive the distribution of transmission probabilities as a function of the distance between leads. This allows us to demonstrate topological effects in the average conductance and the shot noise of the setup. We also consider mesoscopic fluctuations and compute the variance of conductance. This quantity is strongly influenced by topology in the quantum Hall case. All the calculations are carried out assuming localization effects are weak, i.e., in the short length limit. Technically, this amounts to studying 1D non-linear sigma model with a proper topological term and source fields on the semiclassical level. Remarkably, the semiclassical limit of the 1D sigma model can be exactly mapped onto a fully quantum 0D sigma model of a different symmetry class. This allows us to identify the distribution of transmission probabilities with the spectrum of a certain random matrix.