HL 29: Quantum Transport and Quantum Hall Effects

Time: Wednesday 9:30–12:00 Location: EW 561

Invited Talk HL 29.1 Wed 9:30 EW 561

Nonreciprocal charge transport on the edges of a quantum anomalous Hall insulator — •Gertjan Lippertz[1,2], Anjana Uday[1], Andrea Bliesener[1], Lino Pereira[2], Alexey Taskin[1], and Yoichi Ando[1] — [1]Physics Institute II, University of Cologne, Cologne, Germany — [2]Quantum Solid State Physics, KU Leuven, Leuven, Belgium

The quantum anomalous Hall insulator (QAHI) is characterized by a zero longitudinal resistivity and a quantized Hall resistance without the need of an external magnetic field. However, when reducing the device dimensions or increasing the current density, an abrupt breakdown of the dissipationless state occurs. We have previously proposed that this breakdown originates from the electric-field-driven percolation of charge puddles in the 2D bulk states of the compensated thin film [1]. It was recently reported that the interplay between the 1D chiral edge state and the 2D bulk states in a QAHI can give rise to nonreciprocal charge transport [2]. So far, this nonreciprocity was only studied in the broken-down QAHI state at elevated temperatures and at high excitation currents [2], and hence its emergence from the low-current, dissipationless regime remains to be understood. In this talk, we show that the onset of 2D bulk conduction due to breakdown is sufficient to create the nonreciprocal effect, and interestingly, there is a sign change in the nonreciprocity with increasing current, suggesting a crossover in the underlying mechanism of the nonreciprocal transport.

[1] Lippertz et al., Phys. Rev. B 106, 045419 (2022)
[2] Yasuda et al., Nat. Nanotechnol. 15, 831-835 (2020)

HL 29.2 Wed 10:00 EW 561

Visualizing electronic transport in the quantum anomalous Hall regime — •George Ferguson[1], Run Xiao[2], Anthony Richardella[2], Nitin Samarth[2], and Katja Nowack[1] — [1]Laboratory of Atomic and Solid-State Physics, Cornell University — [2]Department of Physics, The Pennsylvania State University

We report a magnetic imaging study of the current distribution in the quantum anomalous Hall regime. We use a scanning superconducting quantum interference device (SQUID) microscope with micrometer scale spatial resolution to image the magnetic fields above Cr-doped (Bi,Sb)2Te3 samples. From these data we reconstruct the local current density, allowing us to visualize the current distribution in our devices. We find that most current flows in the bulk when the transport coefficients are quantized. By combining this observation with images of the equilibrium magnetization, we construct a comprehensive picture of electronic transport in the quantum anomalous Hall regime.

HL 29.3 Wed 10:15 EW 561

Microwave transport in quantum anomalous Hall edge states — •Torsten Röper, Hugo Thomas, Daniel Rosenbach, Christian Dickel, Anjana Uday, Gertjan Lippertz, Alexey Taskin, Yoichi Ando, and Erwann Bocquillon — Physics Institute II, University of Cologne, Cologne, Germany

Magnetically doped topological insulators such as V-doped $(Bi_xSb_{1-x})_2Te_3$ (V-BST) show the quantum anomalous Hall (QAH) effect. These materials exhibit a quantized Hall conductance without an applied external magnetic field, owing to the presence of a non-zero Chern number. A single chiral edge state emerges at the edge of the QAH material and is topologically protected against disorder and perturbations. Microwave transport in chiral edge states allows for investigating the dispersion and velocity of the edge states.

In this context, we conduct microwave measurements on devices using V-BST films grown by molecular beam epitaxy. We measure the transmission of the edge states as a function of temperature, magnetic field and frequency. We determine their velocity and attenuation from the phase and amplitude, respectively. Following recent works, we ascribe the interaction with charge puddles as a primary source of dissipation. We describe this interaction with a circuit model and observe a dispersion consistent with findings in similar materials. As such, it provides a potential material platform for coherent electronic transport in chiral edge states and the generation and manipulation of flying Majorana excitations.

HL 29.4 Wed 10:30 EW 561

Anomalous conductance steps in 3DTI HgTe-based QPCs — •Elisabeth Richter[1], Michael Barth[2], Dmitriy Kozlov[1], Juliane Steidl[1], Klaus Richter[2], and Dieter Weiss[1] — [1]Institut für Experimentelle und Angewandte Physik, Universität Regensburg, 93053 Regensburg, Germany — [2]Institut für Theoretische Physik, Universität Regensburg, 93053 Regensburg, Germany

Previously, 3DTI strained HgTe-based nanowires were studied in an axial magnetic field, exhibiting Aharonov-Bohm type oscillations [1]. Here, we study the conductance of short QPCs of different width and height in a perpendicular magnetic field. The QPCs are fabricated by lithography and etching, resulting in ballistic but non-adiabatic transport. Zero-field gate voltage traces show no quantisation and conductance in the range of 1 to 100 e^2/h. In a quantising magnetic field, pronounced conductance plateaus are observed, coinciding with the position of the integer filling factors of the macroscopic part of the sample. Surprisingly, for narrow QPCs, the values of the plateaus are smaller than expected for the corresponding filling factors. Such behaviour could be considered as trivial impurity scattering; however, we found that certain conductance values are preferred over others. We hypothesise that the QPC acts as a kind of filter whose transmission depends on the structure of the energy bands in the QPC.

[1] Ziegler, J. et al., Phys. Rev. B 97, 035157 (2018)

15 min. break

HL 29.5 Wed 11:00 EW 561

Spin splitting and disorder of Landau levels in HgTe-based Dirac fermions — •Dmitriy Kozlov, Johannes Ziegler, and Dieter Weiss — Experimental and Applied Physics, University of Regensburg, D-93040 Regensburg, Germany

This study conducts experimental exploration into a system of two-dimensional Dirac fermions, utilizing a critical thickness HgTe quantum well in weak magnetic fields. The formation and evolution of Shubnikov-de Haas (SdH) oscillations in the magnetotransport and the capacitive response are studied, complemented by calculations of Landau levels (LLs). It is shown that the behavior of the LLs is influenced not only by the linear dispersion law of the carriers and the Zeeman splitting, but also by the splitting of the Dirac cones in zero magnetic field caused by interface inversion asymmetry (IIA). The measured value of the splitting is 1.5 meV. The behavior of the zero LL is studied and its spin splitting is demonstrated. It is shown that the broadening of the zero LL is several times higher than that of the other levels due to the lack of charge impurity screening.

HL 29.6 Wed 11:15 EW 561

In-plane electric-field effects at transitions between quantum Hall plateaus in InAs-based quantum wells — •Olivio Chiatti[1], Johannes Boy[1], Christian Heyn[3], Wolfgang Hansen[3], and Saskia F. Fischer[1,2] — [1]Novel Materials Group, Humboldt-Universität zu Berlin, 10099 Berlin, Germany — [2]Center for the Science of Materials Berlin, Humboldt-Universität zu Berlin, 12489 Berlin, Germany — [3]Institut für Nanostruktur- und Festkörperphysik, Universität Hamburg, 20148 Hamburg, Germany

The cross-over from quasi-two- to quasi-one-dimensional electron transport is studied in dependence of transverse electric fields and perpendicular magnetic fields, both in the diffusive to quasi-ballistic and in the zero-field to quantum Hall regime. Hall-bars and in-plane gates have been fabricated from an InGaAs/InAlAs/InAs quantum well hosting a 2DEG. Magnetotransport measurements at temperatures down to 50 mK and fields up to 12 T show a high effective Lande-factor of $|g^*| = 16$, allowing to resolve spin-split subbands at magnetic fields of 2.5 T. In the quantum Hall regime, electrostatic change of the effective constriction width enables control of the reflection and transmission of edge channels, allowing to separate fully spin-polarized edge channels at filling factors $\nu = 1$ und $\nu = 2$. A change in the orientation of a transverse in-plane electric field in the constriction shifts the transition between Zeeman-split quantum Hall plateaus by $\Delta B \approx 0.1$ T and is consistent with an effective magnetic field of $B_{eff} \approx 0.13$ T by spin-dependent backscattering, indicating a change in the spin-split density of states.

HL 29.7 Wed 11:30 EW 561

Topological band structure of InAs/GaSb/InAs and

InAs/GaInSb/InAs triple quantum wells — •Sebastian Gebert — Technische Physik, Physikalisches Institut, Am Hubland, D-97074 Würzburg, Germany

Going back to the initial proposal of Kane and Mele [1], the 2D topological insulator (TI) has attracted considerable attention. The first experimental demonstrations of such a TI phase were obtained in HgCdTe/HgTe/HgCdTe and InAs/GaSb quantum wells (QWs). In both cases the TI phase was restricted to cryogenic temperatures either by the strong temperature dependence of the bands or the inherently small bulk bandgap. A promising approach to overcome these limitations was proposed by Ref. [2]. They theoretically demonstrated, that by modifying the known InAs/GaSb QWs with an additional layer it is possible to realize a plethora of different phases, including a TI phase. More precisely, an InAs/GaSb/InAs TI could reach a bulk bandgap of 16 meV and a strained InAs/GaInSb/InAs TI up to 60mV. We here present gate voltage and temperature dependent magnetotransport measurements of InAs/GaSb/InAs and InAs/GaInSb/InAs QWs grown primarily in the TI phase. For later ones, we extract a bulk bandgap of 45 meV and the occuring edge conductivity, which persists up to 40 K, is attributed to the topological edge channels.

[1] C. L. Kane & E. J. Mele, Phys. Rev. Lett. 95, 146802
[2] S. S. Krishtopenko & F. Teppe, Science Advances Vol. 4, NO. 4
[3] C. Avogadri et al., Phys. Rev. Research 4, L042042

HL 29.8 Wed 11:45 EW 561

Giant Negative Magnetoresistance as a Function of the Electron Density — •Lina Bockhorn[1], Dieter Schuh[2], Christian Reichl[3], Werner Wegscheider[3], and Rolf J. Haug[1] — [1]Institut für Festkörperphysik, Leibniz Universität Hannover, Germany — [2]Institut für Experimentelle und Angewandte Physik, Universität Regensburg, Germany — [3]Laboratorium für Festkörperphysik, ETH Zürich, Switzerland

Ultra-high mobility two-dimensional electron gases not only show an increasing number of new fractional filling factors, but also an astonishing robust negative magnetoresistance at zero magnetic field [1 -4]. In-situ variation of the electron density enables a deep insight into the nature of the negative magnetoresistance. Here, we investigate the temperature-dependent giant negative magnetoresistance (GNMR) as a function of the electron density for several temperatures and currents. For low densities, the temperature dependence of the GNMR is described by the electron-electron interaction correction to the conductivity considering mixed disorder [5]. In the case of higher electron densities, a non-linear current dependence is observed which has to be described within the hydrodynamic regime [6].

[1] L. Bockhorn et al., Phys. Rev. B 83, 113301 (2011).
[2] A. T. Hatke et al., Phys. Rev. B 85, 081304 (2012).
[3] L. Bockhorn et al., Phys. Rev. B 90, 165434 (2014).
[4] L. Bockhorn et al., Appl. Phys. Lett. 108, 092103 (2016).
[5] I. V. Gornyi et al., Phys. Rev. B. 69, 045313 (2004).
[6] P. S. Alekseev, Phys. Rev. Lett. 117, 166601, (2016).