HL 24: Topological insulators: mostly interaction with magnetic fields (with MA/TT)

Time: Monday 15:45–17:45 Location: POT 081

HL 24.1 Mon 15:45 POT 081

SQUID devices built form S-TI-S junctions based on mercury telluride (HgTe) — •Luis Maier, Manuel Grimm, Christopher Armes, Christoph Brüne, Hartmut Buhmann, and Laurens W. Molenkamp — Physikalisches Institut (EP3), Universität Würzburg, 97074 Würzburg

In the search for Majorana fermions, one way to show their existence requires an interface of a s wave superconductor and a strong topological insulator (TI) [1]. It has already been shown, that a three-dimensional, strained layer of HgTe shows dominant surface conductance in magnetotransport measurements and thus is considered as a 3D-TI [2]. Here we investigate the interaction of superconducting contacts with Dirac Fermions.

S-TI-S junctions based on HgTe and Nb have already been fabricated and characterized successfully [3]. As a next step in this research we created SQUID structures to further study the current phase relation in these special devices. In this talk we are going to present our recent results searching for deviations from normal behaviour that could point to TI or Majorana interactions.

[1] L. Fu and C. L. Kane, Phys. Rev. Lett. 100, 096407 (2008)
[2] C. Brüne et al., Phys. Rev. Lett. 106, 126803 (2011)
[3] J. Oostinga et al., Phys. Rev. X 3, 021007 (2013)

HL 24.2 Mon 16:00 POT 081

Quantum Interferences of Dirac fermions in Bi2Se3 nanostructures — •Louis Veyrat, Joseph Dufouleur, Romain Giraud, Hannes Funke, Silke Hampel, Christian Nowka, Joachim Schumann, and Bernd Büchner — IFW-Dresden, Dresden, Germany

Recently discovered Z2 topological insulators (TIs) are ideally conducting at their interface only, where a gapless band structure forms. In a strong 3D TI, such as Bi2Se3, surface states are spin-chiral Dirac fermions with an odd number of Dirac cones. However, in real materials, the finite bulk conductivity often prevents the study of surface-state transport. We show that mesoscopic transport measurements can unambiguously reveal the specific properties of spin-chiral Dirac fermions in a Bi2Se3 nanostructure [1]. The quantum conductance of a nanowire exhibits Aharonov-Bohm oscillations which result only from surface-state transport. At very low temperatures, the temperature dependence of their amplitude unveils the quasi-ballistic nature of charge transport, which is the signature of the weak coupling of quasi-particles to their environment. Our results further reveal the weak scattering by structural disorder, giving another evidence of the specific nature of spin-chiral Dirac fermions in a strong 3D TI. Furthermore, new physics evidenced in the study of UCF in a nanowire, could be the signature of a perfectly transmitted mode in a nanowire geometry [2].

[1] J. Dufouleur et al., Phys. Rev. Lett. 110, 186806 (2013)
[2] J. Bardarson et al., Phys. Rev. Lett. 105, 156803 (2010)

HL 24.3 Mon 16:15 POT 081

Thermal and Electrical Transport of Single-Crystalline Bismuth Telluride Nanowires — •Bacel Hamdou[1], Johannes Kimling[1], Johannes Gooth[1], August Dorn[1], Eckhard Pippel[2], Raimar Rostek[3], Peter Woias[3], and Kornelius Nielsch[1] — [1]Institute of Applied Physics, University of Hamburg, Germany — [2]Max Planck Institute of Microstructure Physics, Halle, Germany — [3]Department of Microsystems Engineering, University of Freiburg, Germany

Bi_2Te_3 is a topological insulator (TI), a phase of matter that has a bulk bandgap and gapless electronic surface states protected by time-reversal symmetry. Studying topological surface states via electrical transport measurements is still very difficult due to large bulk contribution to conductivity originating from unintentional doping and the small bulk band gaps, which are typical for TI materials. We report on thermal and electrical transport measurements on individual single-crystalline bismuth telluride nanowires (NWs), synthesized via catalytic growth and post-annealing in a Te-rich atmosphere. The resulting Bi_2Te_3 NWs show reproducible electronic transport properties that are close to those of intrinsic bulk Bi_2Te_3. Further, magnetoresistance measurements were performed at temperatures down to 2 K. The parallel magnetoresistance curves exhibit Aharonov-Bohm oscillations, which indicate the presence of topological surface states. Analyses of Subnikov-de Haas oscillations in perpendicular magnetoresistance yield extremely low two-dimensional carrier concentrations and effective electron masses, and very high carrier mobilities.

HL 24.4 Mon 16:30 POT 081

Ambipolar quantum Hall effect in strained bulk HgTe — •Cornelius Thienel, Jonas Wiedenmann, Steffen Wiedmann, Christoph Brüne, Christopher Ames, Hartmut Buhmann, and Laurens W. Molenkamp — Universität Würzburg, Experimentelle Physik III

Strained bulk HgTe has been identified as three-dimensional topological insulator [Phys. Rev. Lett. **106**, 126803 (2011)]. A Dirac-specific quantum Hall sequence can unambiguously be demonstrated in transport measurements. Furthermore we identify two subsets of Landau levels that originate from the topological surface states.
Improving the quality of the interfaces hosting the surface states by introducing additional buffer and cap layers to the structure increases the carrier mobilities in the topological states and makes it possible to observe the quantum Hall effect of electrons and holes in a wide gate voltage range. The detection of p-type QHE points towards a suppressed interaction between bulk and surface states.

HL 24.5 Mon 16:45 POT 081

Weak antilocalization effects in systems with Dirac-like energy dispersion — •Andreas Budewitz, Mathias Mühlbauer, Bastian Büttner, Grigory Tkachov, Ewelina M. Hankiewicz, Christoph Brüne, Hartmut Buhmann, and Laurens W. Molenkamp — Universität Würzburg, Lehrstuhl für experimentelle Physik III

HgTe quantum wells (QW) have been identified as topological insulator (TI) by appearence of the QSHE [1]. It has been shown that the band structure of HgTe QWs has to be described by a four band model revealing a Dirac like dispersion [2, 3]. Here now we investigate the weak antilocalization (WAL) effect in various n-conducting HgTe QWs. We analyse the magnetoresistance of a set of quasi one-dimensional wires and clearly observe different WAL amplitudes for normal and inverted band ordering which does not depended on the structural inversion asymmetry (SIA). The data demonstrate that a non-universal Berry phase which exceeds π, the characteristic value for gapless Dirac fermions, is needed to explain the different observations in our measurements.

[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)
[2] B. A. Bernevig, T. L. Hughes and S. C. Zhang, Science 318, 1757 (2006)
[3] B. Büttner, C.-X. Liu, G. Tkachov, E. G. Novik, C. Brüne, H. Buhmann, E. M. Hankiewicz, P. Recher, B. Trauzettel, S.-C. Zhang, and L. W. Molenkamp, Nature Phys. 7, 418 (2011)

HL 24.6 Mon 17:00 POT 081

Giant Photocurrents in a Dirac Fermion System at Cyclotron Resonance — •C. Zoth[1], P. Olbrich[1], P. Vierling[1], K.-M. Dantscher[1], G.V. Budkin[2], S.A. Tarasenko[2], V.V. Bel'kov[2], D.A. Kozlov[3], Z.D. Kvon[3], N.N. Mikhailov[3], S.A. Dvoretsky[3], and S.D. Ganichev[1] — [1]Terahertz Center, Regensburg, Germany — [2]Ioffe Institute, St. Petersburg, Russia — [3]Institute of Semiconductor Physics, Novosibirsk, Russia

We report on the observation of giant photocurrents in HgTe/HgCdTe quantum wells (QW) of critical thickness at which a Dirac spectrum emerges [1]. Exciting QW of 6.6 nm width by terahertz radiation and varying an external magnetic field we detected a resonant photocurrent. Remarkably, the position of the resonance can be tuned from negative (-0.4 T) to positive (up to 1.2 T) magnetic fields by means of optical doping. The photocurrent data, accompanied by measurements of radiation transmission, as well as, magnetotransport, prove that the photocurrent is caused by cyclotron resonance in a Dirac fermion system. This allows us to obtain the effective electron velocity $v \approx 7.2 \times 10^5$ m/s. We develop a microscopic theory of the effect and show that the inherent spin-dependent asymmetry of light-matter coupling in the system of Dirac fermions causes the electric current to flow.

[1] P. Olbrich, C. Zoth, P. Vierling *et al.*, *PRB* **87**, 235439 (2013)

HL 24.7 Mon 17:15 POT 081

Quantum Oscillations of Photogalvanic Effect and Spin Orbit Interaction Effect in HgTe Quantum Wells — •K.-M. Dantscher[1], C. Zoth[1], P. Olbrich[1], V.V. Belkov[2], M.A. Semina[2], M.M. Glazov[2], L.E. Golub[3], D.A. Kozlov[3], Z.D. Kvon[3], N.N. Mikhailov[3], S.A. Dvoretsky[3], and S.D. Ganichev[1] — [1]University of Regensburg, Regensburg, Germany — [2]Ioffe Institute, St. Petersburg, Russia — [3]Institute of Semiconductor Physics, Novosibirsk, Russia

We report on the observation of quantum oscillations in HgTe/HgCdTe quantum well (QW) structures of different widths, which are characterized by an inverted, normal and even Dirac like bandstructure [1,2]. Exciting the QWs by terahertz radiation and sweeping an external magnetic field we observed a resonant photocurrent [3] which shows pronounced oscillations. The photocurrent data are accompanied by measurement of photoconductivity, radiation transmission, as well as, magneto-transport. A comparison of the results shows that the photosignal is enhanced at cyclotron resonance position and is modulated by Shubnikov-De Haas oscillations. Furthermore we present a microscopic model of a magnetic field dependent oscillating current taking into account the oscillations of spin polarization and of conductivity.

[1] Z.D. Kvon *et al.*, *JETP Letters* **94**, 816-819 (2011)
[2] A. Bernevig *et al.*, *Science* **314**, 1757 (2006)
[3] P. Olbrich *et al.* *Phys. Lett B* **87**, 235439 (2013)

HL 24.8 Mon 17:30 POT 081

Strong Out-of-Plane Magnetic Anisotropy of Fe Adatoms on Bi_2Te_3 — •Thomas Eelbo[1], Marta Waśniowska[1], Marcin Sikora[2], Michal Dobrzański[2], Andrzej Kozlowski[2], Artem Pulkin[3], Gabriel Autès[3], Ireneusz Miotkowski[4], Oleg Yazyev[3], and Roland Wiesendanger[1] — [1]Institute of Applied Physics, University of Hamburg, Germany — [2]Faculty of Physics and Applied Computer Science, AGH University of Science and Technology, Krakow, Poland — [3]Institute of Theoretical Physics, Ecole Polytechnique Fédérale de Lausanne (EPFL), Switzerland — [4]Department of Physics, Purdue University, West Lafayette, USA

Topological insulators (TIs) are currently in the focus of fundamental physics. The interaction of magnetic impurities with TIs is widely unexplored on the local scale and might potentially entail interesting properties of the TIs in view of applications in spintronics. To this end, we studied the structural, electronic, and magnetic properties of individual Fe atoms adsorbed on a Bi_2Te_3(111) surface by means of scanning tunneling microscopy/spectroscopy (STM/STS), X-ray absorption spectroscopy and X-ray magnetic circular dichroism (XMCD) at low temperatures. STM reveals the existence of two different Fe species. Density functional theory-based calculations let us assign these to atoms adsorbed on the fcc/hcp hollow sites. STS proves the existence of characteristic resonances for each type and XMCD evidences a strong magnetic out-of-plane anisotropy of the Fe moments in agreement with our calculations.