HL 52: Topological insulators: Structure and electronic structure (with DS/MA/O/TT)

Time: Wednesday 15:00–16:30 Location: ER 270

HL 52.1 Wed 15:00 ER 270

New electron states at the Bi/InAs(111) interface — K Hricovini[1,2], J-M Mariot[3], •L Nicolaï[1,2,7], U Djukic[1], M C Richter[1,2], O Heckmann[1,2], T Balasubramanian[4], M Leandersson[4], J Sadowski[4], J Denlinger[5], I Vobornik[6], J Braun[7], H Ebert[7], and J Minár[7,8] — [1]LPMS, UCP,Cergy, France — [2]DSM-IRAMIS, SPEC, CEA-Saclay, France — [3]LCP-MR, UPMC Univ. Paris 06/CNRS, France — [4]MAX-lab, Lund Univ., Sweden — [5]ALS, Berkeley, USA — [6]EST, Trieste, Italy — [7]LMU Münich, Germany — [8]Univ. of West Bohemia, Plzeň, Czech Republic

The Bi(111) surface is a prototype system to study Rashba-split surface states. Theoretical studies [1] predicted non-trivial topological surface states appearing on a single bi-layer of Bi(111) and a more complex behaviour was suggested for a variable film thickness as a function of layer thickness [2]. This clearly indicates that the electronic properties of thin films of this material are far from being understood. Here we present combined theoretical and ARPES studies of the electronic structure of Bi(111) films grown on InAs(111). Bi growth is epitaxial and a monocrystal of very high quality is obtained after depositing several monolayers. The ARPES experiments on these samples show several new types of electronic states. It is shown that a part of these new states corresponds to novel bulk-like features. These features are well reproduced by the one-step model of photoemission as implemented in the SPR-KKR package [3].[1] M. Wada et al., Phys. Rev. B 83, 121310 (2011). [2] Z. Liu et al., Phys. Rev. Lett. 107, 136805 (2011). [3] H. Ebert, D. Ködderitzsch, J. Minár, Rep. Prog. Phys. 74, 096501 (2011).

HL 52.2 Wed 15:15 ER 270

Ultrafast currents at the surface of the topological insulator Bi_2Se_3 — •Lukas Braun[1], Luca Perfetti[2], Gregor Mussler[3], Markus Münzenberg[4], Martin Wolf[1], and Tobias Kampfrath[1] — [1]Fritz-Haber-Institut Berlin (MPG) — [2]Ecole Polytechnique Palaiseau — [3]Forschungszentrum Jülich — [4]Universität Greifswald

Optical excitation of topological insulators (TIs) can launch electron currents along the TI surface whose direction can be controlled by varying the polarization of the driving light [J. W. McIver *et al.*, Nat. Nanotech. **7**, 96]. So far, photocurrents have been detected with a time resolution from DC to picoseconds [C. W. Luo *et al.*, Adv. Opt. Mat. **1**, 804]. Since electrons moving through a solid typically undergo scattering on a 100fs time scale, it is highly desirable to generate and detect TI photocurrents with femtosecond time resolution in a contact-free manner. For this purpose, we excite n-doped Bi_2Se_3 (Fermi energy at 300meV) crystals with a femtosecond laser pulse (10fs, 1.55eV). The resulting photocurrent gives rise to the emission of a broadband terahertz (THz) electromagnetic pulse (1 to 20THz) whose transient electric field is detected by means of electro-optic sampling. We present a method that allows us to extract the transient current $j(t)$ from the measured field $E(t)$. The AC photocurrents are found to be dominated by shift currents along the surface and photo-Dember injection currents into the bulk. We finally discuss the origin of $j(t)$ and implications for the dynamics of photoexcited TI electrons.

HL 52.3 Wed 15:30 ER 270

Observation of the photon drag effect in epitaxially grown $(Bi_{1-x}Sb_x)_2Te_3$ based topological insulators — •H. Plank[1], L. E. Golub[2], P. Olbrich[1], T. Herrmann[1], S. Bauer[1], V. V. Bel'kov[2], G. Mussler[3], J. Kampmeier[3], D. Grützmacher[3], and S. D. Ganichev[1] — [1]University of Regensburg, Regensburg, Germany — [2]Ioffe Institute, St. Petersburg, Russia — [3]Jülich Aachen Research Alliance (JARA-FIT), Jülich, Germany

We report on the observation of a terahertz (THz) radiation induced photon drag effect in epitaxially grown $(Bi_{1-x}Sb_x)_2Te_3$ three-dimensional topological insulators. We demonstrate that the excitation with polarized radiation results in a dc electric photocurrent. While at normal incidence a current arises due to the photogalvanic effect in the surface states, caused by asymmetrical scattering of Dirac fermions [1], at oblique incidence it is overweighted by the trigonal photon drag effect. The currents are generated in n- and p-type $(Bi_{1-x}Sb_x)_2Te_3$ samples with various composition applying linearly and circularly polarized THz radiation. Results are analysed in terms of phenomenological theory and microscopic model based on transfer of photon momentum to free carriers resulting in an asymmetric distribution of electrons (holes) in k-space. Our analysis describes well all experimental findings including e.g. variation of the angle of incidence, radiation polarization and frequency. The observed trigonal photon drag and photogalvanic effect provide an opto-electronic method to study high frequency transport of Dirac fermions even at room temperature.

[1] P. Olbrich *et al.*, Phys. Rev. Lett. **113**, 096601(2014)

HL 52.4 Wed 15:45 ER 270

Cyclotron Resonance Induced Spin Polarized Photocurrents in Surface States of a 3D Topological Insulator — •K.-M. Dantscher[1], D.A. Kozlov[2], Z.D. Kvon[2], P. Faltermeier[1], M. Lindner[1], P. Olbrich[1], C. Zoth[1], G.V. Budkin[3], S.A. Tarasenko[3], V.V. Bel'kov[3], N.N. Mikhailov[2], S.A. Dvoretskii[2], D. Weiss[1], and S.D. Ganichev[1] — [1]University of Regensburg, Regensburg, Germany — [2]Institute of Semiconductor Physics, Novosibirsk, Russia — [3]Ioffe Institute, St. Petersburg, Russia

We report on the observation of cyclotron resonance (CR) induced photocurrents excited by cw radiation, with frequencies of 2.54, 1.62 and 0.69 THz in a 3D topological insulator based on 80 nm strained HgTe films. To support the complex study, including optical, opto-electronic and electron transport experiments, various sample designs have been used. The measurements were done in a wide range of temperatures (1.6 to 120 K). We demonstrate that the photocurrent is generated in the topologically protected surface states. Studying the resonance response in the gated samples we examined the behaviour of the photocurrent and Dirac fermions cyclotron mass upon variation of Fermi energy. For large gate voltages we also detected CR in the bulk HgTe with the mass about two times larger than that obtained for the surface states. Based on this data we develop a microscopic theory of the effects and show that the asymmetry of light-matter coupling in the system of Dirac fermions subjected to an external magnetic field causes the electric current to flow. We show that the current is spin polarized.

HL 52.5 Wed 16:00 ER 270

Response of the topological surface state to surface disorder in $TlBiSe_2$ — Florian Pielmeier[1], •Andreas Eich[2], Gabriel Landolt[3,4], Bartosz Slomski[3,4], Julian Berwanger[1], Alexander A. Khajetoorians[5], Jens Wiebe[2], Roland Wiesendanger[2], Jürg Osterwalder[3], Franz J. Giessibl[1], and J. Hugo Dil[3,4,6] — [1]Institute of Experimental and Applied Physics, Universität Regensburg, D-93040 Regensburg, Germany — [2]Department of Physics, University of Hamburg, Jungiusstrasse 11, D-20355 Hamburg, Germany — [3]Physik-Institut, Universität Zürich, Winterthurerstrasse 190, CH-8057 Zürich, Switzerland — [4]Swiss Light Source, Paul Scherrer Institut, CH-5232 Villigen, Switzerland — [5]Institute of Molecules and Materials, Radboud University, 6500 GL Nijmegen, Netherlands — [6]Institut de Physique de la Matière Condensée, Ecole Polytechnique Fédérale de Lausanne, CH-1015 Lausanne, Switzerland

By a combination of experimental techniques we show that the topmost layer of the topological insulator $TlBiSe_2$ as prepared by cleavage is formed by irregularly shaped Tl islands. No trivial surface states are observed in photoemission, which suggests that these islands can not be regarded as a clear surface termination. The topological surface state is, however, clearly resolved in photoemission experiments. This is interpreted as a direct evidence of its topological self-protection and shows the robust nature of the Dirac cone like surface state.

HL 52.6 Wed 16:15 ER 270

Wet etch process for HgTe nanostructure fabrication — •Kalle Bendias[1], Erwann Bocquillon[1], Alex Hughes[2], Christoph Brüne[1], Hartmut Buhmann[1], and Laurens W. Molenkamp[1] — [1]EP3, Physikalisches Institut, Universität Würzburg — [2]Department of Physics, Stanford University

Topological insulators (TI) are a new class of material with outstanding spin properties. Grown in 2d quantum wells HgTe does not only host Quantum Spin Hall edge channels [1][2], but also a giant Rashba splitting [3]. Both could lead to numerous applications in spintronic devices. In order to perform experiments such as spininjection, -probing

[3] or quantum point contact collimation [4] a high carrier mobility and i.e. a long ballistic mean free path is essential.

The conventional processing method using ion milling to define the structure strongly affects these surface properties on small microstructures. In this talk the development and results of an alternative lithography etch method using KI:I:HBr as wet etchant are presented. Measurements on microstructures will be shown, indicating comparable mobilities on big and small structures.

[1] Markus König et al., Journal of the Physical Society of Japan 77.3 (2008), S. 031007.

[2] C. Brüne et al., Nature Physics 6.6 (2010), S. 448-454.

[3] J. Hinz et al., Semiconductor science and Technology 21.4 (2006), S 501-506.

[4] L.W. Molenkamp et al., Phys. Rev. B 41, 1274 (1990)