HL 35: Focus Session: Topological Insulators on Coupled Quantum Wells (joined session with TT)

Time: Tuesday 9:30–12:45 Location: POT 151

Invited Talk HL 35.1 Tue 9:30 POT 151

Edge conduction in the 2D topological insulator candidate InAs/GaSb — •Susanne Mueller, Matija Karalic, Christopher Mittag, Lars Tiemann, Thomas Tschirky, Quansheng Wu, Alexey A. Soluyanov, Atin Nath Pal, Christophe Charpentier, Matthias Troyer, Werner Wegscheider, Klaus Ensslin, and Thomas Ihn — Physics Department ETH Zurich, 8093 Zurich, Switzerland

We have studied transport measurements in mesoscopic Hall bars in the electrically tunable double quantum well structure InAs/GaSb. Helical edge states are predicted to dominate transport in the hybridization gap at zero magnetic field. We measure the non-local resistances and find a scaling according to Landauer-Büttikers expectations for helical edge modes [1]. No dependence on edge length could be observed in these devices, despite recent findings of trivial edges in this material system [2, 3]. To deepen the discussion, we are currently investigating the edge length dependence over a broader range of sample sizes and complete the discussion with clear experimental signature for the inverted phase [4] and the effect of strain on the bulk band structure [5], having in mind that an optimized bulk insulator is a necessary starting point for an edge study.

[1] S. Mueller et al., Phys. Rev. B 92, 081303 (2015)
[2] F. Nichele et al., New J. Phys. 18, 083005 (2016)
[3] B.-M. Nguyen et al., Phys. Rev. Lett. 117, 077701 (2016)
[4] M. Karalic, S. Mueller et al., Phys. Rev. B 94, 241402 (2016)
[5] L. Tiemann, S. Mueller et al., arXiv: 1610.06776

HL 35.2 Tue 10:00 POT 151

Topological Dirac Semimetals in GeSbTe vdW Heterostructures — •Peter Schmitz[1,3], Wei Zhang[2], Yuriy Mokrousov[3], and Riccardo Mazzarello[1] — [1]Institute for Theoretical Solid State Physics, RWTH Aachen — [2]CAMP Nano, Xi'an Jiaotong University, China — [3]IAS-1 and JARA, Forschungszentrum Jülich

We investigate the spectral and topological properties of hexagonal $TeSb[Te(GeTe)_n]SbTe$ van-der-Waals (vdW) heterostructures (GST-KH) as a function of strain, GeTe content and spin-orbit coupling (SOC) using density functional theory. We show that C_{3v} rotation symmetry stabilizes a massive 3D topological Dirac semimetal (TDSM) phase [1] in the entire family, thus going beyond previous topological insulator (TI) + normal insulator (NI) superlattice (SL) models [2]. The TDSM bulk Dirac cones move along k_z, proportional to the SOC profile and hybridization balance of corresponding interface states that gives rise to emergent magnetic gauge fields. The avoided crossings naturally allow perturbative hopping to build a tunable TDSM-heterostructure model and to include the c_S protected massive TDSM phase into the SL TI-to-NI transition as an expanded onset of the critical point where TDSM and 3D TI features merge. We attribute the TDSM dispersion of GST-KH to the internal $X(AX)_n$ film between polarizing SbTe caps and thereby create a link to generalized AX_2. To our knowledge, this is the first example of a (massive) TDSM in a vdW superlattice [*].

[*] doi.org/10.13140/RG.2.2.15113.85606
[1] B. Yang and N. Nagaosa, Nature Commun. 5, 4898 (2014)
[2] J. Tominaga et al, Adv. Mat. Inter. 1, 1300027 (2014)

HL 35.3 Tue 10:15 POT 151

Fractional quantum Hall effect in the $N = 2$ Landau level in bilayer graphene — Georgi Diankov[1], •Chi-Te Liang[1,2], François Amet[3,4], Patrick Gallagher[1], Menyoung Lee[1], Andrew Bestwick[1], Kevin Tharratt[1], William Coniglio[5], Jan Jaroszynski[5], Kenji Watanabe[6], Takashi Taniguchi[6], and David Goldhaber-Gordon[1] — [1]Department of Physics, Stanford University, Stanford, California 94305, USA — [2]Department of Physics, National Taiwan University, Taipei 106, Taiwan — [3]Department of Physics, Duke University, Durham, North Carolina 27708, USA — [4]Department of Physics and Astronomy, Appalachian State University, Boone, NC 28608, USA — [5]National High Magnetic Field Laboratory, Tallahassee, Florida 32310, USA — [6]Advanced Materials Laboratory, National Institute for Materials Science, 1-1 Namiki, Tsukuba 305, Japan

To date, most fractional quantum Hall (FQH) studies have focused on the $N = 0$ lowest Landau level (LL). Here we report transport measurements of FQH states in the $N = 2$ LL (filling factors $4 < |\nu| < 8$) in bilayer graphene, a system with spin and valley degrees of freedom in all LLs, and an additional orbital degeneracy in the 8-fold degenerate $N = 0/N = 1$ LLs. In contrast with recent observations of particle-hole asymmetry in the $N = 0/N = 1$ LLs of bilayer graphene. The particle-hole symmetric FQH states in the $N = 2$ LL display energy gaps of a few Kelvin, comparable to and in some cases larger than those of fractional states in the $N = 0/N = 1$ LLs.

Invited Talk HL 35.4 Tue 10:30 POT 151

Progress in Edge Channel Transport of Two-Dimensional Topological Insulators — •Hartmut Buhmann — Physikalisches Institut, EP3, Universität Würzburg, Würzburg, Germany

The discovery of the quantum spin Hall (QSH) effect is already ten years old. However, an undisturbed edge channel transport has rarely been reported especially for samples which exceed a few micrometers in size, even though the QSH-states are protected against backscattering by time reversal symmetry. The reasons are manifold but mainly due to the fact that two-dimensional topological insulators are based on narrow gap semiconductors. Small disturbances and inhomogeneity may already result in potential fluctuations which introduce locally metallic electron or hole puddles. Edge channels traversing such puddles are no longer protected and backscattering destroys the expected perfect quantized conductance.

In this presentation I will review the experimental observations on two-dimensional topological insulators and give examples of how one can achieve almost perfect quantization in narrow gap samples. Taking special care during the fabrication process and taking advantage of charge accumulation at certain interfaces of the sample layer stack it becomes possible to observe quantized edge channel conductance even in sample exceeding the elastic mean free path. With these samples it is now possible to address various still open questions on the specific properties of the transport in helical edge channel as for example aspects of the magnetic field and temperature dependence.

Coffee Break

Invited Talk HL 35.5 Tue 11:30 POT 151

Transport and capacitance in HgTe-based topological insulators — •Dieter Weiss — Universität Regensburg, D-93040 Regensburg, Germany

The discovery of 2D and 3D topological insulators (TI) has opened an exciting area of condensed matter physics. It has been theoretically predicted and recently shown experimentally [1-3] that strained HgTe films constitute a 3D TI with a high-mobility 2D-electron gas enclosing the insulating bulk of HgTe. Here, I will show both transport and capacitance data obtained from different metal-oxide HgTe devices. Using top gates we can tune the gate voltage and thus explore quantum transport and quantum capacitance at different positions of the Fermi level E_F. Experiments on mesoscopic structures like nanowires and antidot superlattices made from strained 3D-HgTe films provide further evidence of the peculiar nature of topological surface states.

Work done in collaboration with D. A. Kozlov, D. Bauer, J. Ziegler, H. Maier, R. Fischer, S. Weishäupl, Z. D. Kvon, N. N. Mikhailov, and S. A. Dvoretsky

[1] C. Brüne et al., Phys. Rev. Lett. **106**, 126803 (2011)
[2] D. A. Kozlov et al., Phys. Rev. Lett. **112**, 196801 (2014)
[3] D. A. Kozlov et al., Phys. Rev. Lett. **116**, 166802 (2016)

HL 35.6 Tue 12:00 POT 151

Gate-tunable spin-charge conversion in single-layer graphene — •Masashi Shiraishi[1], Sergey Dushenko[1], Yuichiro Ando[1], Hiroki Ago[2], Taishi Takenobu[3], Susumu Kuwabata[4], and Teruya Shinjo[1] — [1]Kyoto University, Japan — [2]Kyushu University, Japan — [3]Nagoya University, Japan — [4]Osaka University, Japan

The small spin-orbit interaction of carbon atoms in graphene promises a long spin diffusion length and the potential to create a spin field-effect transistor. However, for this reason, graphene was largely overlooked as a possible spin-charge conversion material. In this presentation, an electric gate tuning of the spin-charge conversion voltage signal in single-layer graphene is reported [1]. Using spin pumping from an yttrium iron garnet ferrimagnetic insulator and ionic liquid top gate, we determined that the inverse spin Hall effect is the dominant spin-charge conversion mechanism in single-layer graphene. From the gate dependence of the electromotive force we showed the dominance of the intrinsic over Rashba spin-orbit interaction, a long- standing question in graphene research. Our study shows a simple spatial inversion symmetry breaking is not sufficient for generating the inverse Rashba-Edelstein effect, which is contrary to a conclusion in the other study [2].

References: [1] S. Dushenko, M. Shiraishi et al., Phys. Rev. Lett. 116, 166102 (2016). [2] J.B.S. Mendes et al., Phys. Rev. Lett. 115, 226601 (2015).

Invited Talk HL 35.7 Tue 12:15 POT 151

Giant Spin-Orbit Splitting in Inverted InAs/GaSb Double Quantum Wells — •Fabrizio Nichele[1], Morten Kjaergaard[1], Henri J. Suominen[1], Rafal Skolasinski[2], Michael Wimmer[2], Binh-Minh Nguyen[3], Andrey A. Kiselev[3], Wei Yi[3], Marko Sokolich[3], Michael J. Manfra[4], Fanming Qu[2], Arjan J. A. Beukman[2], Leo P. Kouwenhoven[2], and Charles M. Marcus[1] — [1]Center for Quantum Devices and Station Q Copenhagen, Niels Bohr Institute, University of Copenhagen, Universitetsparken 5, 2100 Copenhagen, Denmark — [2]QuTech, Delft University of Technology, 2600 GA Delft, The Netherlands — [3]HRL Laboratories, 3011 Malibu Canyon Road, Malibu, California 90265, USA — [4]Department of Physics and Astronomy and Station Q Purdue, Purdue University, West Lafayette, Indiana 47907 USA

We present transport measurements and numerical simulations that reveal a giant spin-orbit splitting of the bands in inverted InAs/GaSb quantum wells close to the hybridization gap. The splitting results from the interplay of electron-hole mixing and spin-orbit coupling, and can be larger than the hybridization gap. We experimentally investigate the band splitting as a function of top gate voltage for both electronlike and holelike states. Unlike conventional, noninverted two-dimensional electron gases, the Fermi energy in InAs/GaSb can cross a single spin-resolved band, resulting in full spin-orbit polarization. In the fully polarized regime we observe exotic transport phenomena such as quantum Hall plateaus evolving in e^2/h steps and a nontrivial Berry phase.