HL 31: Focus Session: Dirac fermions in solid-state systems (HL, jointly with TT)

The observation of massless Dirac fermions in monolayer graphene has initiated a new area of research exploring charge carriers that behave relativistically within solid-state systems. Both massless and massive Dirac fermions are studied in a growing range of materials that include most prominently few-layer graphene and topological insulators. The symposium will highlight some of the recent developments in this quickly advancing field. (Organizers: Roland Winkler, Northern Illinois University, and Ewelina Hankiewicz, Universität Würzburg)

Time: Tuesday 9:30–12:15 Location: H2

Topical Talk HL 31.1 Tue 9:30 H2

Localization at graphene system and topological insulator edges — •Markus Buttiker — University of Geneva, Dept. of Theoretical Phys., 24 Quai E. Ansermet, 1211 Geneva, Switzerland

Graphene systems share a number of features with topological insulators. We investigate localization phenomena at the edges of these two systems [1,2]. In bilayer graphene subject to a strong perpendicular electric field we have found that in the presence of a strongly disordered edge a sequence of localized states appears. Interestingly the localization length depends only on the size of the bulk gap but is otherwise universal, i.e. independent of the type and strength of the disorder [1]. The appearance of these localized states reflects the marginal topological properties of bilayer graphene, a bipartite square lattice with similarly disordered edges does not show edge states localized at the edge.

In two-dimensional topological insulators such as HgTe/CdTe there exists a pair of helical edge states which are protected against non-magnetic disorder. However, if time-reversal symmetry is removed by the application of a magnetic field the protection is removed and these states localize. We investigate the divergence of the localization length as the magnetic field tends to zero and find that the localization length saturates at higher fields [2].

[1] Jian Li, Ivar Martin, Markus Buttiker, Alberto F. Morpurgo, Nat. Phys. 7, 38-42 (2011); Phys. Scr. Physica Scripta T146, 014021 (2012).

[2] Pierre Delplace, Jian Li, Markus Büttiker , Phys. Rev. Lett. 109. 246803 (2012).

Topical Talk HL 31.2 Tue 10:00 H2

Controlling Quantized Edge Transport in Two-dimensional Topological Insulators — Viktor Krueckl, Sven Essert, and •Klaus Richter — Institut für Theoretische Physik, Universität Regensburg, 93040 Regensburg, Germany

Robustness of edge channels against disorder scattering is an outstanding feature of two-dimensional topological insulators (TIs). Here we consider quantized transport and mesoscopic interference phenomena in HgTe-based TIs, systems where the quantum spin Hall state has first been experimentally observed [1]. On the one hand, we discuss mechanisms to steer the spin orientation, and thereby the charge flow between different edges in TI constrictions that turn out to provide rather robust spin transistor functionality [2]. On the other hand, we study the combined effect of a time-reversal symmetry breaking magnetic field and disorder on transport to explore the limits of topological protection and the competition between reflectionless modes, metallic behavior and Anderson localization. In particular, transport in hybrids composed of normal conducting and TI regions shows peculiar quantization phenomena.

[1] M. König et al., Science **318**, 766 (2007);

[2] V. Krueckl, K. Richter, Phys Rev. Lett. **107**, 086803 (2011).

Topical Talk HL 31.3 Tue 10:30 H2

First-principles studies of Dirac-cones in graphene and 3D topological insulators — •Gustav Bihlmayer — Peter Grünberg Institut and Institute for Advanced Simulation, Forschungszentrum Jülich and JARA, Jülich, Germany

The unique properties of graphene, in particular the two Dirac-cones determining the transport phenomena in this material, led the way to the first theoretical proposal of the quantum spin Hall effect at the edges of a graphene ribbon by Kane and Mele in 2005. Since spin-orbit coupling (SOC) effects are extremely weak at the Dirac points, this phenomenon is hard to observe experimentally. I discuss several theoretical proposals and experiments that have been made to enhance intrinsic SOC effects. Here, density functional theory (DFT) provides a quantitative tool to predict the properties of these two-dimensional topological insulator phases.

In three-dimensional topological insulators topologically protected edge states form Dirac-cones with chiral spin texture (in contrast to the spin-degenerate Dirac-cone of graphene). We discuss the spin-polarization and -orientations in this state for Bi and Se chalcogenides and its interaction and modification with magnetic adatoms. Also here DFT results will be compared to experiments where available.

Coffee break

Topical Talk HL 31.4 Tue 11:15 H2

Lifetime broadening of topological surface states with and without magnetic moments — •Oliver Rader[1], Markus Scholz[1], Jaime Sánchez-Barriga[1], Andrei Varykhalov[1], Dmitry Marchenko[1], Emile Rienks[1], Andrey Volykhov[2], and Lada Yashina[2] — [1]Helmholtz-Zentrum Berlin — [2]Moscow State University

The lifetime broadening of the angle-resolved photoemission signal from the surface states of Bi_2Se_3 and Bi_2Te_3 is studied. It is revealed that hexagonal warping in Bi_2Te_3 introduces an anisotropy for electrons propagating along $\overline{\Gamma}$-$\overline{K}$ and $\overline{\Gamma}$-$\overline{M}$. Moreover, we show that the electron-phonon coupling strength is substantial and in good agreement with theoretical predictions. The small Fermi surface is believed to limit the number of phonon modes for electron scattering. In line with this, the imaginary part of the self-energy from the surface state electrons declines with higher binding energies. In addition, we find that Fe surface impurities have a much stronger influence on the lifetimes as compared to Ag. This is independent of the sign of the doping which is p-type when Fe is deposited at low temperature.

Topical Talk HL 31.5 Tue 11:45 H2

Transport in topological insulators - experiments — •Christoph Brüne — Experimentelle Physik 3, Physikalisches Institut, Universität Würzburg

The prediction and discovery of topological insulators (TIs) has attracted wide interest in the physics community during the past years. The first topological insulator state was predicted and discovered in 2 dimensional systems. I will present our results concerning the quantum spin Hall effect in HgTe quantum wells. The quantum spin Hall effect is the signature state of a 2-dimensional topological insulator.

In 3 dimensions this new state of mater is characterized by conducting Dirac type surface states while the bulk of the material remains insulating. Such surface states have been observed in e.g. Bi2Te3, Bi2Se3 and Sb2Te3. These materials do, however, exhibit large defect densities paired with low carrier mobilities. So far this prevented transport studies in the quantum Hall regime of 3D TIs. Recently, however, we succeeded in using strained bulk HgTe as 3D TI. This enabled us to measure the quantum Hall effect from the 3D TI surface state in transport experiments.