北京大学量子材料科学中心
International Center for Quantum Materials, PKU

Seminar

Quantum Transport of Surface Dirac Fermions in Topological Insulators – from "half-integer" quantum Hall effect to "half-integer" AB oscillations

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Time: 4:00pm, July 7, 2015 (Tuesday)
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Venue: Room w563, Physics building, Peking University
地点：北京大学物理楼，西563会议室

Abstract

Three-dimensional topological insulators (TI) are gapped band insulators in the bulk, but have nontrivial topologically protected spin-helical gapless Dirac fermion conducting states on the surface. Such "topological surface states" (TSS) are promising platforms to realize a rich variety of novel physics and device applications, ranging from majorana fermions to topological electronics/spintronics. It has been challenging to study electronic transport properties of TSS because real TI materials often contain other parallel conduction channels (such as the bulk as well as topologically-trivial bulk-band-bending-induced surface inversion layers, both could exhibit 2D-like transport)[1,2] that can overwhelm or mask the TSS transport. In the past few years, significant progresses have been made to find better TI materials to reduce or eliminate conductance contribution from bulk states. For example, we have recently realized an "intrinsic" topological insulator[3], $BiSbTeSe_2$ (BSTS1112), with unprecedentedly low bulk conduction (undetectable at low temperature) and thickness-insensitive surface-dominated conductance (observable even close to room temperature in thin films). In this talk, I will discuss several experiments on bulk-insulating TIs showing unique transport physics of TSS spin-helical Dirac fermions, where their pi Berry's phase can give rise to a characteristic half-integer (1/2) shift in both the quantum Hall effect (QHE) and Aharonov-Bohm (AB) oscillations. The observed well-developed QHE arising from the Dirac TSS[3] has novel physics not encountered in previously-studied 2D electron systems (including graphene). We also observe intriguing features when the top and bottom surfaces are gated to opposite carriers or near Dirac point, such as a minimal conductivity of $\sim 4e^2/h$ at zero magnetic field, and an intriguing nu=0 "dissipative quantum Hall state". In TI nanoribbons (NR)[4] of Bi_2Te_3 where TSS effectively lives on cylinder, the gate voltage induces an oscillation in the conductance, as well as an alternation of the phase (between 0 and pi) in the magnetic-field-induced AB oscillations, periodic in the TSS Fermi momentum (k_F) whenever TR circumference encloses an integer multiple of Fermi wavelengths[5]. This is a manifestation of the circumferential quantization of the TSS forming a series of 1D subbands with a magnetic field driven, periodic topological transition with opening/closing of a gap at Dirac point and disappearance/appearance of a characteristic 1D helical mode at integer/half-integer flux quanta. This 1D spin-helical mode is unique to cylindrical TSS and can provide a promising, robust platform to realize a 1D topological superconductor via proximity. Some initial efforts studying Josephson junctions and supercurrent transport in such TINR-superconductor hybrid devices may be described if time allows.

References: [1]H. Cao *et al*. PRL 108, 216803 (2012); [2]H. Cao *et al*. arXiv:409.3217 (2014); [3]Y. Xu *et al*. Nat. Phys. 10, 956 (2014); [4]L.A. Jauregui *et al*., Sci. Rep. 5, 8452 (2015); [5]L. A. Jauregui *et al*. arxiv: 1503.00685 (2015)