Transport properties of spin-helical Dirac fermions in disordered quantum confined systems

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Abstract

Quantum wires of 3D topological insulators offer a serious way to unveil the topological properties of the band structure and are promising systems for the search of robust signatures of topological conductivity and superconductivity in condensed matter [1]. Due to the strong degree of disorder typical for such materials, disorder remains a key limitation for such systems and prevents the emergence of transport properties specific for spin-helical Dirac fermions.

Here, we reveal that the interaction between the static disorder and the quasi-particles of the 3D topological insulator surface states is considerably reduced due to the spin texture of the band structure by investigating the transconductance properties of a Bi2Se3 nanoribbon [2]. This result suggests that the ballistic or quasi-ballistic regime could be achieved in narrow structures of 3D topological insulator like nanowires [3]. Furthermore, the typical surface states transport length measured in our nanostructures corresponds to an energy broadening () that is of the same order of magnitude or even smaller than the level spacing (Δ) in nanowires of Bi2Se3 or Bi2Te3, an unusual result for highly-disordered mesoscopic nanostructures[3,4]. As a result, contrary to the expected diffusive case corresponding to " Δ, the conductance fluctuation are found to be non-universal. Theory shows that such a unique behavior is specific to spin-helical Dirac fermions with strong quantum confinement, which retain ballistic properties over an unusually large energy scale due to their spin texture.

Following our experimental work, we also present the results of a theoretical investigation of the transport properties quantum wires of topological insulators, in the high energy regime usually considered experimentally and we show that the spin-helicity and the linear dispersion of the band structures leads to specific conductance and shot noise properties as well as Ahoronov-Bohm oscillations.

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