Quantum transport in Dual-Gated Topological Insulator n–p–n Junctions

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Abstract

The time-reversal-symmetry-protected topological surface states (TSS) of three-dimensional topological insulators host spin-momentum-locked Dirac fermions, providing a promising platform for spintronics, Majorana physics, and novel quantum transport phenomena [1]. Electrostatic p–n and n–p–n junctions offer a powerful route to control the charge and spin degrees of freedom of TSS. In the presence of an external magnetic field, TI surface states quantize into Landau levels, giving rise to chiral, spin-polarized edge modes and enabling spin-dependent quantum Hall transport [2-3]. Despite their potential, experimental studies of TI p–n junctions remain limited due to challenges in fabrication and probing [4]. In this work, we investigate local and nonlocal transport across electrostatically defined n–p–n junctions in dual-gated BiSbTeSe2 devices with and without magnetic fields. With increasing magnetic field beyond a critical onset value, we observe a splitting of the Dirac resistance peak into a peak–plateau structure, attributed to Landau-level formation in regions of opposite carrier polarity and to the equilibration of counter-propagating chiral edge states. Combined local and nonlocal measurements are used to probe the role of surface states in different junction regions and the resulting current distribution, both in zero field and in the quantum Hall regime, enabling a systematic study of transport across topological insulator n–p–n junctions.

References

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