Magnetic-Field-Induced Localization in 2D Topological Insulators

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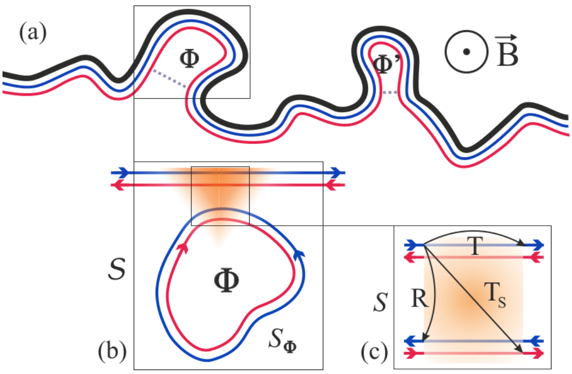
Localization of the helical edge states in quantum spin Hall insulators requires breaking time-reversal invariance. In experiments, this is naturally implemented by applying a weak magnetic field B [1,2]. We propose a model based on scattering theory that describes the localization of helical edge states due to coupling to random magnetic fluxes [3]. We find that the localization length is proportional to B^{-2} when B is small and saturates to a constant when B is sufficiently large. We estimate especially the localization length for the HgTe/CdTe quantum wells with known experimental parameters.



(a) Helical edge states in a disordered QSHI in a uniform magnetic field. Occasional occurrences of constrictions along the edge lead to Fabry-Perot-type loops where Aharonov-Bohm phases due to magnetic fluxes can accumulate. (b) The scattering of the helical edges by one of these loops, described by a scattering matrix S, can be divided into two parts: the scattering between two pairs of helical edge states (S), and the propagation of one of these pairs around the loop (S). (c) Three types of scattering probabilities, T, R and Ts, that are relevant to the scattering between two pairs of helical edge states.

[1] M. Konig, S. Wiedmann, C. Brune, A. Roth, H. Buhmann, L. W. Molenkamp, X.-L. Qi, and S.-C. Zhang, Science 318, 766 (2007)
[2] C.Brüne, A. Roth, H. Buhmann, E. M. Hankiewicz, L. W. Molenkamp, J. Maciejko, X.-L. Qi, and S.-C. Zhang, Nature Physics 8, 486 (2012)
[3] Pierre Delplace, Jian Li and Markus Büttiker, Phys. Rev. Lett. 109, 246803 (2012)