Majorana modes in three-dimensional topological insulators with warped surface state

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HEXAGONAL WARping IN TOPoLOGICAL INSULATORS

Many theoretical predictions about magnetic and transport properties of topological insulators were made on the basis of a simplified model, when the topological surface states were described with an isotropic Dirac cone. However, such isotropic models are only valid if the chemical potential lies near the Dirac point, while in realistic topological insulators it usually lies well above this point, where the Dirac cone distortion can be any more neglected.

For example, the Fermi surface of Bi2Te3 topological insulator observed by angle resolved photoemission spectroscopy (ARPES) is nearly a hexagon, having snowflake-like shape: it has relatively sharp tips extending along six directions and curves inward in between [1,2]. Moreover, the shape of constant energy contour is energy dependent, working from a snowflake to a hexagon and then to a circle near the Dirac point.

Recently it was realized that without violation of the symmetry the simplified Hamiltonian can be extended to higher order terms in the momentum. Namely, Fu found an unconventional hexagonal warping term in the surface band structure [3]. The effective Hamiltonian of surface states then reads

\[ \hat{H}(k) = -\mu + i(\sigma_x k_y - k_x \sigma_y) + \hat{H}_w(k) \]

where the hexagonal warping term is given by

\[ \hat{H}_w(k) = \frac{2}{3} k_y^3 \sigma_y. \]

Here \( \epsilon_k = k_y \sigma_y + \sigma_x (\sigma_x k_y - k_x \sigma_y) \) are the Pauli matrices in spin space, \( \sigma_x, \sigma_y, \sigma_z \) are Pauli matrices in spin space, \( \mu \) denotes the chemical potential at the Fermi level, \( v \) is a Fermi velocity, and \( J \) is the hexagonal warping strength.

References: