Effect of nuclear spins on transport properties of two-dimensional topological insulators

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We investigate the influence of nuclear spins on the resistance of helical edge states of two-dimensional topological insulators (2DTIs) [1]. Via the hyperfine interaction, nuclear spins allow electron backscattering [2,3], otherwise forbidden by time reversal symmetry. We identify two backscattering mechanisms, depending on whether the nuclear spins are ordered or not. Their temperature dependence is distinct but both give resistance, which increases with the edge length, decreasing temperature, and increasing strength of the electron-electron interaction. Overall, we find that the nuclear spins will typically shut down the conductance of the 2DTI edges at zero temperature.

[1] Chen-Hsuan Hsu, Peter Stano, Jelena Klinovaja, and Daniel Loss, arXiv:1703.03421.
[2] Pavel Aseev, Jelena Klinovaja, and Daniel Loss, Phys. Rev. B 95, 125440 (2017).
[3] Jelena Klinovaja, Peter Stano, Ali Yazdani, and Daniel Loss, Phys. Rev. Lett. 111, 186805 (2013).

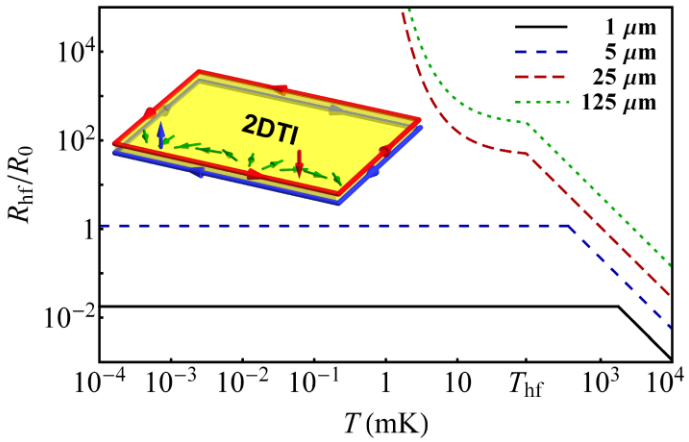

Figure 1: Temperature (T) dependence of the resistance induced by thermally disordered nuclei for various edge lengths L. Inset: 2DTI helical edges with up-spin (blue) and the down-spin (red) electrons moving in opposite directions (routes are separated for clarity). The spin quantization (z) axis is perpendicular to the plane of the 2DTI. The nuclear spins at the boundaries (green arrows) are ordered [33, 34] below the transition temperature, and become randomly oriented (not shown) above it. For clarity, spins are drawn only at one edge.