Dissipative Edge Transport in Disordered Axion Insulator Films

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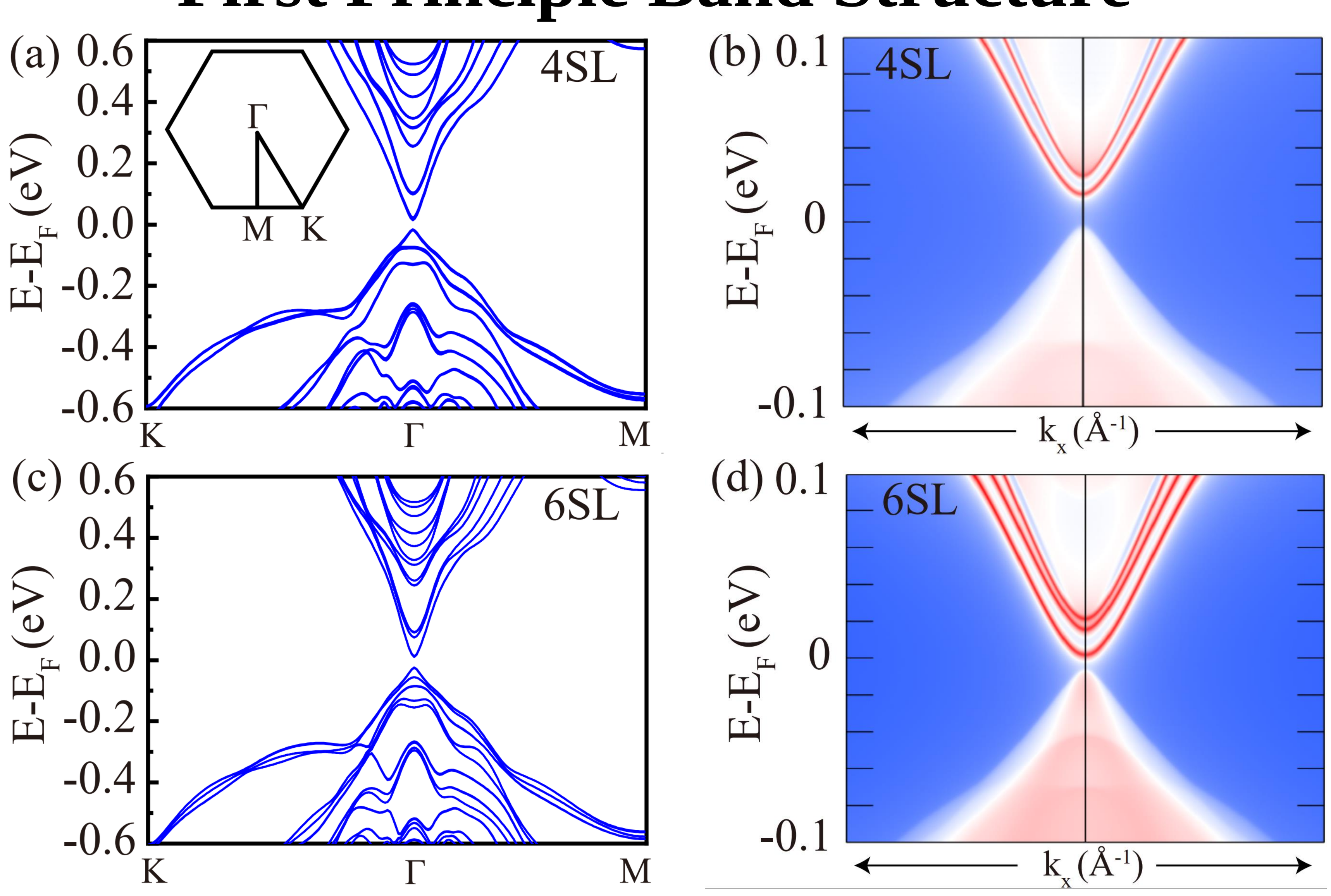
Introduction

We investigate the role of disorder in the edge transport of axion insulator films. We predict by first-principles calculations that even-number-layer MnBi2Te4 have gapped helical edge states. The random potential will dramatically modify the edge spectral function to become gapless. We further study the edge transport in this system by Landauer-Büttiker formalism, and find such gapless edge state is dissipative and not immune to backscattering, which would explain the dissipative nonlocal transport in the axion insulator state observed in six septuple layer MnBi2Te4 experimentally. In particular, we propose the longitudinal resistance can be greatly reduced by adding an extra floating probe even if it is not used.

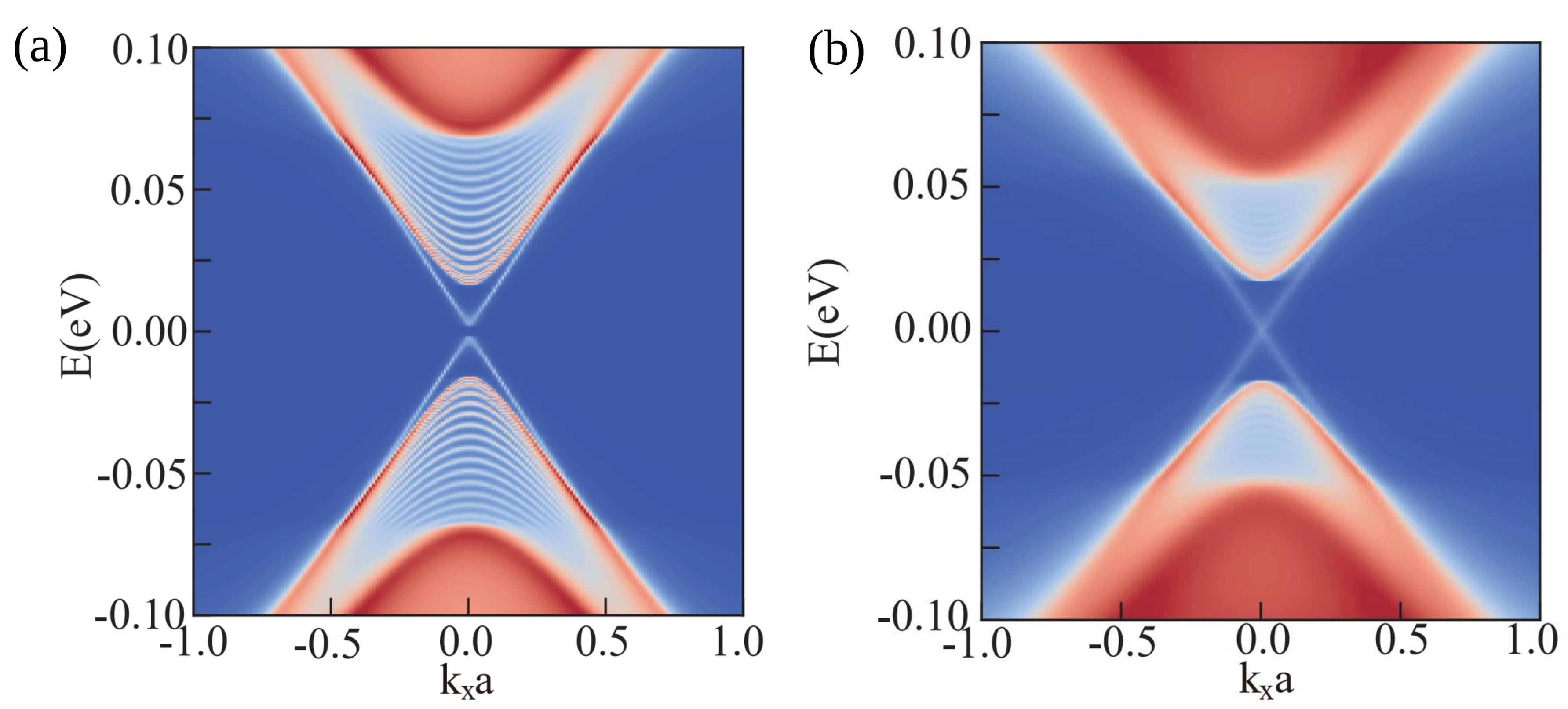
Results

First Principle Band Structure



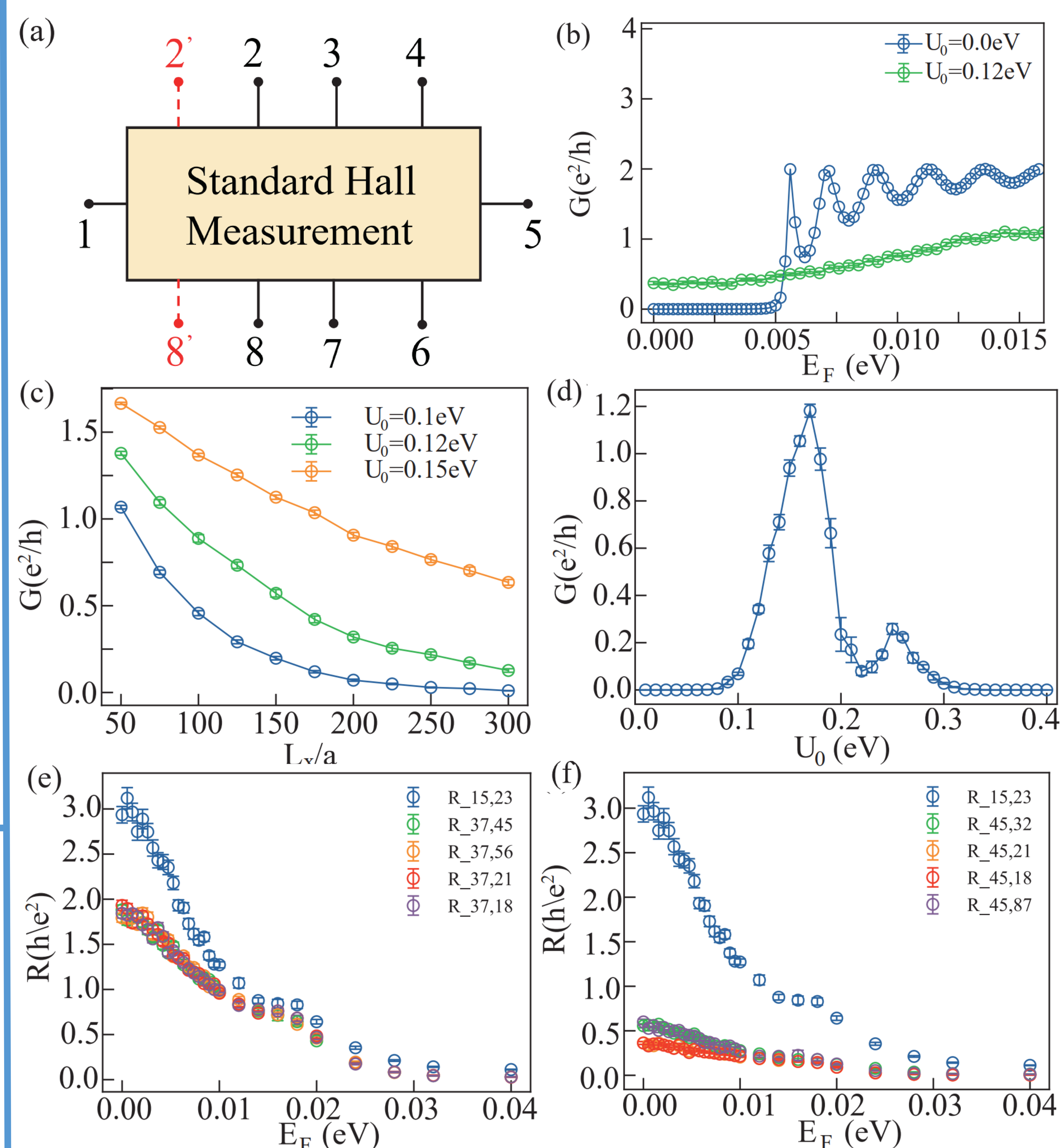
(a) & (b) Band structure for 4 SL and 6SL $MnBi_2Te_4$. The energy dispersion of the semi-infinite film along edge Γ*M* is plotted for (b) 4SL and (6) SL, respectively. The gapped edge states a re clearly seen around Γ point as red lines dispersing in the 2D bulk gap.

Disorder Averaged Spectral Function



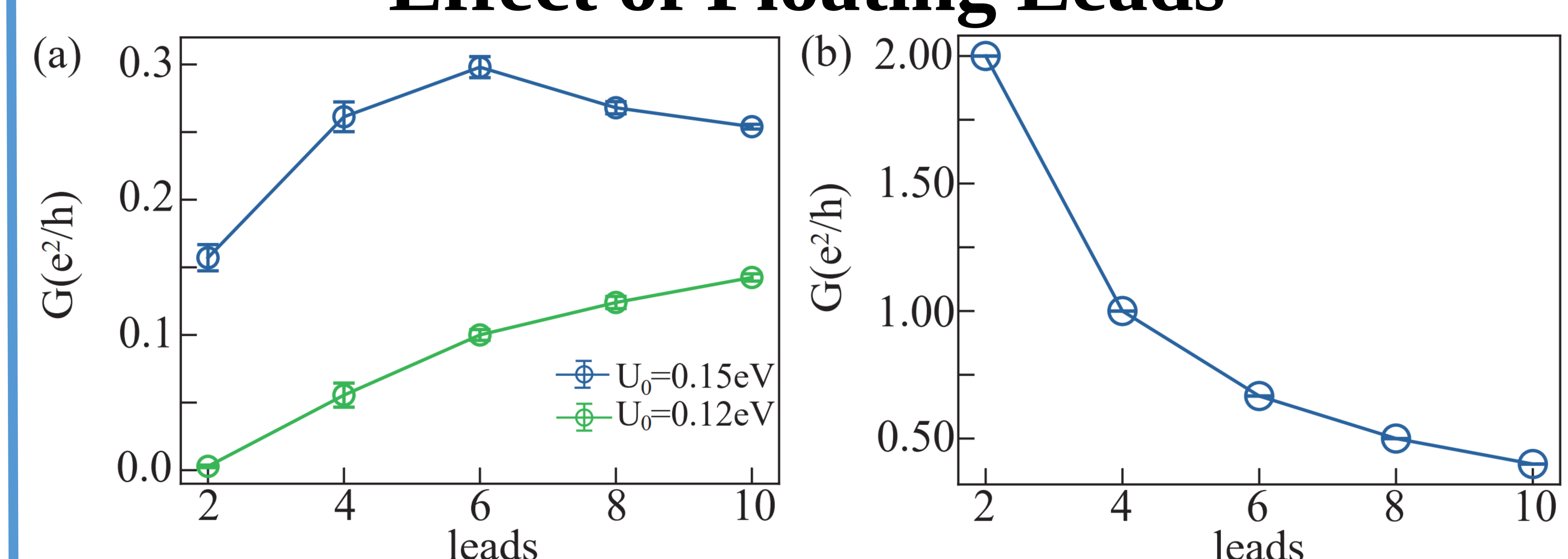
(a) & (b) The edge spectral function within the SCBA of disorder strength $U_0 = 0.06\ eV$ and $U_0 = 0.1\ eV$, respectively. The disorder is given by a random on-site potential.

Nonlocal Transport



(a) Schematic drawing of a Hall bar device. (b) The two terminal conductance G vs E_F with different disorder strength U_0. (c) G vs L_x at $E_F = 0$ for different U_0. (d) G vs U_0 at $E_F = 0$. (e, f) The local and non-local resistance $R_{ij,kl}$ in eight terminal device as function of E_F with $U_0 = 0.1eV$.

Effect of Floating Leads



The longitudinal conductance vs number of floating leads for (a) dissipative helical state in 6SL $MnBi_2Te_4$ with different U_0 and $E_F = 0$, and (b) dissipationless helical state in QSH. The floating leads is placed equal spacing between two leads where the longitudinal resistance is being measured.

Set the sample has length as L and the transmission amplitude between near by leads is $T = k \sim \exp(-l/l_m) \sim \exp(-L/Nl_m)$. The longitudinal resistance is

$$\rho = \frac{N+1}{2k} \sim \frac{N+1}{2\exp(-L/Nl_m)}.$$

Conclusion

Disorder with moderate strength would modify the edge transport in axion insulator thin film. As 4SL sample has a larger edge gap, such gapped state would persist even with disorder

Reference

[1] Liu Z, Qian D, Jiang Y, et al. Dissipative Edge Transport in Disordered Axion Insulator Films[J]. arXiv preprint arXiv:2109.06178, 2021.