Tunable Helical Edge States in van der Waals Materials

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Helical conductors, systems that have no bulk conduction but support dissipationless conducting states at their edges, may be engineered to realize Majorana statistics for quantum computation. Underlying these remarkable systems are the non-trivial topology of electronic structure in the bulk, arising band inversion in the bulk and crossing of conductance and valence bands at the system boundary. In helical conductors, these counterpropagating states carry different spin quantum numbers, protecting the crossing and preventing a gap from opening in the spectrum of edge states. Traditional helical conductors, such as those achieved in topological insulator systems, are typically not tunable in situ, and helical conduction is only achieved over a narrow range of parameters.

In this presentation I will discuss helical edge states that are achievable and tunable in few-layer van der Waals materials. In Bernal-stacked trilayer and tetralayer graphene, we observe helical edge states at moderate and strong magnetic fields, respectively, arising from the competing effects of inter-layer coherence, electrostatic polarization and exchange interaction. As the interlayer potential and magnetic field varies, we observe a series of quantum transitions among the phases that host 2, 1 and 0 helical edge states on each edge. Our work highlights the complex competing symmetries in few-layer graphene and the rich quantum phases in this seemingly simple system[1, 2]. Lastly, in thin exfoliated Bi_4I_4 samples, which is a quasi-1D topological insulator and candidate for higher order topological states, we observe gate tunable magneto-transport and Josephson current. Our combined transport, photoemission, and theoretical results indicate that the gate-tunable channels consist of novel gapped side surface states, a 2D TI in the bottommost layer, and helical hinge states of the upper layers[3].

References

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