Talk Titles & Abstracts

Fractional Quantum Hall Effect in Flat Bands: a New Goal to Strive for in Topological Physics.

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Abstract

The recent achievement of the long-standing goal of taking the "zero magnetic field" (integer) quantum anomalous Hall effect (or Chern Insulator) from its humble origins as a theorist 's toy model, that merely provided a "proof of principle", to the final stage of a true physical realization, has opened up the path to the fruitful combination of QHE with superconductivity, (which breaks the "protective symmetry" relevant to the QHE). Our understanding of the fractional FQHE has been largely based on Landau levels, together with the Laughlin wavefunction and its non-Abelian generalizations, but the "anomalous" (zero-field) FQHE has been demonstrated (by exact numerical diagonalization of toy models) to in-principle occur in fractionally-filled Chern insulator bands that have been fined-tuned to be "flat". If such states (especially if non-Abelian) can be physically realized, their combination with superconductivity promises to be even more useful, perhaps for "universal" quantum computing. This poses the question of how to design such materials, which will require a fuller understanding of the physics of the "flux attachment" that gives rise to the FQHE. I will argue that we have not yet achieved a full understanding of the physics of flux attachment, and that this will be needed to guide the rational design of fractional Chern insulator materials. I will present a view of the FQHE based on "non-commutative geometry" and sketch how these ideas might be transferred from Landau levels to topological flat bands.

Chiral Majorana Fermion Modes in a Quantum Anomalous Hall Insulator-Superconductor Structure for Topological Quantum Computing*

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Abstract

In 1937, Ettore Majorana proposed a particle being its antiparticle. Since its inception, Majorana has been under intensive pursuit both theoretically and in experiment. Recent interest in robust topologically protected quantum computing has accelerated the experimental quest of Majorana. The talk will begin from the experimental efforts of the quest of dissipationless transport: quantum Hall without magnetic field, quantum spin Hall to quantum anomalous Hall (QAH), which was enabled by a long term effort in the materials growth of topological insulator. When the QAH edge states interface with a superconductor, the Dirac electron space

is transformed to the Nambu space, hosting Majorana fermions via a pairing energy of the superconductor. We will describe our experimental efforts to show the convincing evidence of quantized signature of the one-dimensional chiral Majorana fermion at the proper topological phase transitions under the reversal of the magnetization. In addition, a similar half quantized signature obtained from measurements of the side contacts to the structure further supports the presence of MFs. This half-integer quantized conductance plateau (0.5 e2/h) gives a firm signature of the elusive Majorana fermion for the first time. More recently, the half-integer quantized conductance was also realized in a similar InSb nanowire and a superconductor heterostructure. This finding gives a new direction for robust topological quantum computing to minimize the de-coherence challenge.
I will discuss several possible pathways for realizing the elemental qubits and operations. The use of QAH is of critical importance as the dissipationless edge state of QAH offers a long coherent length in mm length scales; this is the key for scaling to a large number of quantum bits. One of these approaches is to pattern a 2-dimensional structure into nanowires, which make the Majorana Chiral modes into zero modes, for which quantum bits may be coded.

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Quantum Anomalous Hall Effect and Interface Superconductivity in Two-Dimensional Systems

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Abstract

Two-dimensional systems are fertile grounds for finding exotic behavior of electrons, as exemplified by the quantum Hall effect in semiconductor heterostructures and high temperature superconductivity in layered copper oxides. In this talk we will present recent progresses along these directions in different two-dimensional material systems grown by molecular beam epitaxy. The first topic is about the quantum anomalous Hall effect, which is the quantum Hall effect in zero magnetic field due to spontaneous magnetization. In order to realize this effect, the two-dimensional electron system must satisfy the stringent requirements of being topological, ferromagnetic, and insulating simultaneously. By using a variety of experimental techniques, we achieved accurate control of the electronic and magnetic properties of Cr doped (Bi,Sb)2Te3 topological insulator thin films, which eventually led to the observation of quantum anomalous Hall effect. Recent developments based on the magnetic topological insulator systems will also be discussed. The second topic is about the superconductivity in monolayer FeSe film grown on SrTiO3 substrate. We found that the superconducting gap size and transition temperature are about an order of magnitude larger than that in bulk FeSe crystal. We propose that the enhancement of superconductivity is mainly due to the charge transfer and strong electron-phonon coupling at the interface between FeSe and SrTiO3. The interface enhanced/induced superconductivity may become a generic approach for finding new and better superconductors.