Reviewing the quantum anomalous Hall effect

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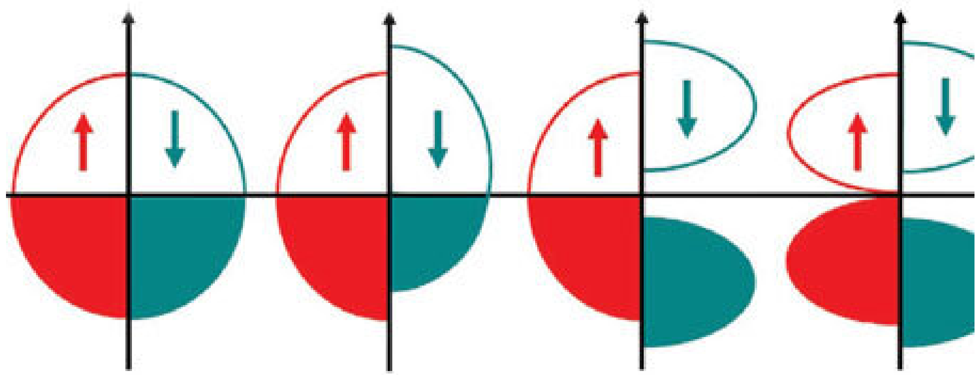

Credit: FLEET

A collaboration across three FLEET nodes has reviewed the fundamental theories underpinning the quantum anomalous Hall effect (QAHE).

QAHE is one of the most fascinating and important recent discoveries in condensed-matter physics.

It is key to the function of emerging quantum materials, which offer potential for ultra-low energy electronics.

QAHE causes the flow of zero-resistance electrical current along the edges of a material.

QAHE in topological materials: key to low-energy electronics

Topological insulators, recognized by the Nobel Prize in Physics in 2016, are based on a quantum effect known as the quantum anomalous Hall effect (QAHE).

"Topological insulators conduct electricity only along their edges, where one-way edge paths conduct electrons without the scattering that causes dissipation and heat in conventional materials," explains lead author Muhammad Nadeem.

QAHE was first proposed by 2016 Nobel-recipient Prof Duncan Haldane (Manchester) in the 1980s, but it subsequently proved challenging to realize QAHE in real materials. Magnetic-doped topological insulators and spin-gapless semiconductors are the two best candidates for QAHE.

The quantum Hall effect (QHE) is a quantum-mechanical version of the Hall effect, in which a small voltage difference is created perpendicular to a current flow by an applied magnetic field.

The quantum Hall effect is observed in 2-D systems at low temperatures within very strong magnetic fields, in which the Hall resistance undergoes quantum transitions—i.e., it varies in discrete steps rather than smoothly.

QAHE describes an unexpected quantisation of the transverse Hall resistance, accompanied by a considerable drop in longitudinal resistance.

QAHE is referred to as anomalous because it occurs in the absence of any applied magnetic field, with the driving force instead provided by either a spin-orbit coupling or intrinsic magnetization.

Researchers seek to enhance these two driving factors in order to strengthen QAHE, allowing for topological electronics that would be viable for room-temperature operation.

It's an area of great interest for technologists," explains Xiaolin Wang. "They are interested in using this significant reduction in resistance to significantly reduce the power consumption in electronic devices."

"We hope this study will shed light on the fundamental theoretical perspectives of quantum anomalous Hall materials," says co-author Prof Michael Fuhrer (Monash University), who is Director of FLEET.

The study

The collaborative, theoretical study concentrates on these two mechanisms:

large spin-orbit coupling (interaction between electrons' movement and their spin)
strong intrinsic magnetization (ferromagnetism)

Four models were reviewed that could enhance these two effects, and thus enhance QAHE, allowing topological insulators and spin fully-polarized zero-gap materials (spin gapless semiconductors) to function at higher temperatures.

"Among the various candidate materials for QAHE, spin-gapless semiconductors could be of potential interest for future topological electronics/spintronics applications," explains Muhammad Nadeem.

Quantum Anomalous Hall Effect in Magnetic Doped Topological Insulators and Ferromagnetic Spin-Gapless Semiconductors—A Perspective Review was published in the journal *Small* in September 2020.

More information: Quantum Anomalous Hall Effect in Magnetic Doped Topological Insulators and Ferromagnetic Spin-Gapless Semiconductors—A Perspective Review. *Small*. doi.org/10.1002/smll.201904322

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