Observation of 3D acoustic quantum Hall states

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(a) Schematics of the A-A stacking hexagonal lattice. (b) First Brillouin zone and the distribution of the Weyl points. The arrows show their shifts direction by changing the on-site energies of A and B. (c) Inhomogeneous configuration with gradient on-site energy. (d) Equi-energy contours of the surface states at the energy of Weyl points with different on-site energies. (e) Projected dispersions of a parallelogram-shaped structure along the $k_z$ direction. (f) Wave function distributions of the edge states. Credit: Science China Press
The quantum Hall effect (QHE) is one of the most notable discoveries in condensed matter physics, opening the door to topological physics. Extending QHE into three dimensions is an inspiring but challenging endeavor. This difficulty arises because the Landau levels in three dimensions extend into bands along the direction of the magnetic field, preventing the opening of bulk gaps.

Recently, a feasible scheme has been proposed in Weyl semimetals, whose Fermi arc states on opposite surfaces are connected through the bulk Weyl points to form a complete Fermi loop, and under the magnetic field, one-dimensional edge states are induced on the boundary of the opposite surface. However, the unique edge states have yet to be experimentally observed.

In a new paper published in *Science Bulletin*, researchers from Shanxi University and Wuhan University of China, theoretically proposed and experimentally demonstrated the three-dimensional QHE for acoustic waves in a Weyl acoustic crystal. In particular, the interesting one-dimensional edge states on the opposite surfaces have been directly observed.

Since the magnetic field has no effect on acoustic waves, a pseudomagnetic field was constructed, whose effect on acoustic waves is similar to that of magnetic fields on electrons. A common strategy for constructing acoustic wave PMFs is to introduce a structural gradient.

In this paper, the gradient structure was introduced by varying the acoustic cavities corresponding to the on-site energy. In the process, the Fermi arcs connecting the Weyl points simultaneously shifted along the same direction, so both the bulk and surface states felt the same pseudomagnetic field. With the pseudomagnetic field, the surface states formed Landau levels, and the one-dimensional edge states were generated and localized near the diagonal hinges.
In the experiment, an acoustic crystal sample was fabricated using 3D printing technology, and the one-dimensional edge states were directly observed by measuring the acoustic pressure field in the sample.

"This study may open new ways for manipulating acoustic waves, which serve as the basis for acoustic devices with unconventional functions. It provides an ideal and tunable platform to explore the Hall physics, and can extend to other artificial structures, such as the optical and cold atomic systems," the researchers say.


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