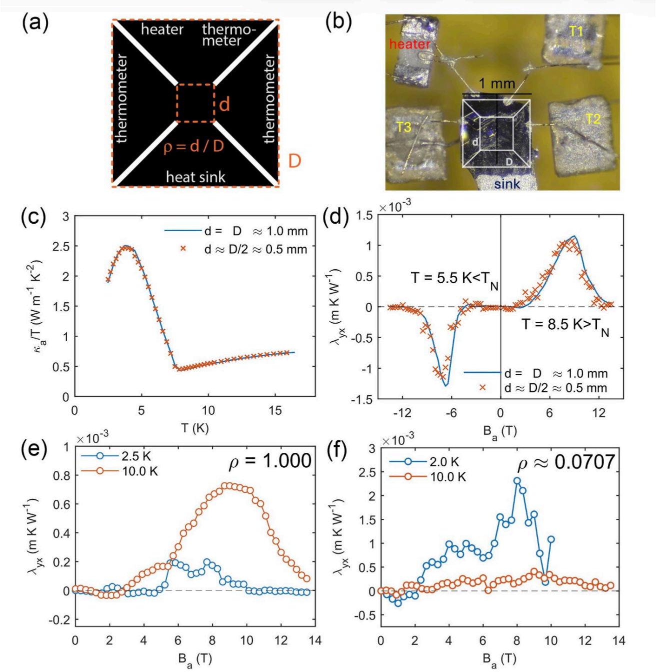
Geometric Engineering of Thermal Transport Reveals Chiral Fermion Edge Modes in a Kitaev Quantum Material



Geometry-engineered thermal transport measurements reveal enhanced low-temperature thermal Hall response arising from chiral Majorana edge modes in α-$RuCl_3$, providing evidence for fractionalized fermionic excitations in a Kitaev quantum material.

Heda Zhang, Gábor B. Halász, Sujoy Ghosh, Stephen Jesse, Thomas Z. Ward, David A. Tennant, Michael A. McGuire, and Jiaqiang Yan. "Evidence of Chiral Fermion Edge Modes through Geometric Engineering of Thermal Hall Effect in α-$RuCl_3$." *Physical Review Letters* 136, 226301 (2026)

Scientific Achievement

Developed and experimentally demonstrated a new geometry-based approach for identifying topological quantum states by engineering thermal transport pathways. Using tailored sample geometries, the work distinguishes fermionic Majorana edge transport from conventional bosonic heat transport in the Kitaev candidate α-$RuCl_3$.

Significance and Impact

Introduces a fundamentally new experimental methodology for detecting topological quantum matter through device geometry rather than material-dependent signatures alone. The approach establishes a scalable platform for identifying chiral spin liquids and provides the foundation for future thermal anyon interferometry and topological quantum information devices.

Research Details

- Developed geometrically engineered α-$RuCl_3$ devices using focused ion beam fabrication to create controlled thermal constrictions.
- Demonstrated that thermal Hall transport depends strongly on device geometry at low temperature, precisely as predicted for chiral fermion edge modes but inconsistent with purely phononic or magnonic transport.
- Combined precision thermal transport experiments with quantitative theoretical modeling of edge–bulk thermalization, establishing geometric transport as a powerful probe of fractionalized quantum excitations.

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- **NQISRC Intellectual Role:** *[Lead]*
  - The Quantum Science Center led the theoretical concept, experimental realization, and interpretation of geometry-engineered thermal transport measurements as a new platform for detecting topological quantum excitations and chiral edge modes.
- **NQISRC Funding Role:** *[Majority]*
- **Explanation of Funding Institution Contributions:**
  - The Quantum Science Center provided the primary support for developing the geometric transport concept, thermal Hall measurements, theoretical modeling of edge–bulk thermalization, and interpretation of chiral Majorana edge transport. CNMS supported focused ion beam nanofabrication, while BES supported complementary materials and instrumentation.