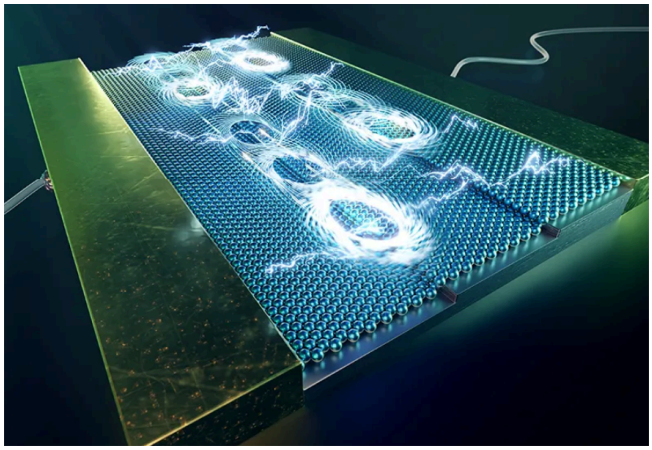
[Vol. 96] MANA Reveals Atomic-Scale Rails for Guiding Superconducting Vortices

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Atomic steps steer vortex motion in ultrathin superconductors, enabling tunable one-dimensional flow



Title:Quantum vortices in superconductors moving along atomic steps
Caption:In superconductors with atomic-scale thickness, atomic steps guide the motion of superconducting vortices like rails.
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Researchers at the Research Center for Materials Nanoarchitectonics (MANA), one of the centers under the National Institute for Materials Science (NIMS), Japan, discovered that atomic-scale steps can guide superconducting vortices in an ultrathin superconductor. Vortices moved more than 1,000 times more easily along the steps than across them, and this guiding effect could be tuned by temperature and magnetic field.

Superconducting vortices are tiny quantum objects whose movement can strongly influence how superconductors behave. Controlling their direction of motion could therefore be important for developing ultralow-power superconducting technologies. However, directional control of vortices in two-dimensional superconductors has remained challenging. Achieving such control could help develop future superconducting devices that consume less power while improving processing efficiency.

Addressing this challenge, a research team led by Takashi Uchihashi from Research Center for Materials Nanoarchitectonics (MANA), National Institute for Materials Science, Japan, investigated an ultrathin superconductor with regularly arranged atomic steps on its surface. Scanning tunneling microscopy confirmed the parallel steps and directly visualized vortices located along them. Their findings were published in the journal Physical Review B on July 30, 2026.

Four-terminal resistance measurements revealed that vortices moved more than 1,000 times more easily along the atomic steps than across them at intermediate magnetic fields. *"Our study shows that atomic-scale steps can act as effective rails that guide superconducting vortices, and that this guiding effect can be tuned simply by changing the temperature or magnetic field,"* said Uchihashi. Between about 0.10 and 0.20 T, vortices flowed freely along the steps without being hindered by pinning, forming one-dimensional pinning-free vortex flow, while at the lowest temperatures their motion was governed by quantum tunneling.

Overall, the findings demonstrate that one-atom-high surface steps can act as effective rails for guiding quantum vortices, opening possibilities for controlling vortex motion and heat flow in future superconducting technologies.

References

Journal	Physical Review B
Title	Anisotropic transport of Josephson vortices in atomic-layer superconductors on vicinal surfaces
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List of Research Highlights

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