A fresh spin in quantum physics: The 'spin triplet' supercurrent

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For the first time, scientists have created a “spin triplet” supercurrent through a ferromagnet over a long distance. Achieved with a magnet developed at Brown University and the University of Alabama, the feat upends long-standing theories of quantum physics – and may be a boon to the budding field of “spintronics,” where the spin of electrons, along with their charge, is harnessed to power computer chips and circuits. Results are published in *Nature*.

Superconductivity occurs when electrical current moves without resistance, a phenomenon that gave rise to particle accelerators, magnetic resonance imagining machines and trains that float, friction-free, on their tracks.

Under quantum physics theory, conventional superconductivity is not supposed to occur in ferromagnets. When electrons pass through these crystalline materials, they realign in ways that won't allow resistance-free conductivity. While supercurrent through a ferromagnet has been observed, it moved only an extremely short distance before resistance kicked in.

But a team of scientists from Delft University of Technology, Brown University and the University of Alabama has now accomplished this physics feat, creating a "spin triplet" supercurrent through a unique ferromagnet.

As explained in the current issue of Nature, the team's experimental system converts the spin, or rotation, of pairs of electrons in such a way that suggests they exist in three quantum states inside the new magnet. There's the standard "spin up" and "spin down" – a reference to an electron's angular momentum – but also a middle state. Picture a planet that was thought to rotate two ways: With its North Pole pointing up or pointing down. But now it's found that this planet can be made to rotate on its side, with its North Pole pointing out in a 90-degree angle.

While such a "spin triplet" conversion in a ferromagnet was predicted in theory, the team offers the first experimental evidence for the phenomenon.

The team also showed that this current travels a comparatively long distance. In previous experiments, current passed through a ferromagnet sandwiched between superconductors spaced one nanometer apart. Under the new system, the space between superconductors was 300 nanometers apart.

"It's a beautiful thing," said Gang Xiao, a Brown professor of physics. "What we've done was considered almost impossible. But physicists never take 'no' for an answer."

Xiao spent eight years perfecting the ferromagnet with Brown graduate students and colleagues from the University of Alabama. The magnet is black, about the size of a postage stamp, and measures only 1,000 atoms thick. To make it, chromium oxide was heated until it vaporized. That vapor was transported onto a titanium oxide film, so that only a single crystal layer coated the titanium material.

The magnet was sent to scientists at Delft University of Technology in the Netherlands. A team there placed dozens of tiny superconducting electrodes on top of the magnet then used an electron beam to cut the electrodes, creating the 300-nanometer gap between them. Scientists then tested the system to measure the flow of current.

Xiao hopes that the new ferromagnet can help create technologies in the hot new field of "spintronics," short for spin-based electronics. While conventional electronics tap the charge of an electron to conduct current, spintronic devices use the spin as well as the charge. The promise: smaller, faster and cheaper computer memory storage and processing.

Already, spintronic technology can be found in computer hard drives. A magnetic version of a random access memory device and a spin-based transistor are under development. So are "quantum computers," which can perform hyperfast calculations.

Xiao said the spin triplet current created with the ferromagnet would allow for new control in spintronics development.

"Once you understand this new behavior of electrons, you can apply the knowledge in new ways to commercial products," he said. "The consequences can be significant."

Source: Brown University

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