Scientists find asymmetry in topological insulators

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New research shows that a class of materials being eyed for the next generation of computers behaves asymmetrically at the sub-atomic level. This research is a key step toward understanding the topological insulators that may have the potential to be the building blocks of a super-fast quantum computer that could run on almost no electricity.

Scientists from the Energy Department's National Renewable Energy Laboratory contributed first-principles calculations and co-authored the paper "Mapping the Orbital Wavefunction of the Surface States in 3-D Topological Insulators," which appears in the current issue of *Nature Physics*. A topological insulator is a material that behaves as an insulator in its interior but whose surface contains conducting states.

In the paper, researchers explain how the materials act differently above and below the Dirac point and how the orbital and spin texture of topological insulator states switched exactly at the Dirac point. The Dirac point refers to the place where two conical forms – one representing energy, the other momentum – come together at a point. In the case of topological insulators, the orbital and spin textures of the sub-atomic particles switch precisely at the Dirac point. The phenomenon occurs because of the relationship between electrons and their holes in a semiconductor.

This research is a key step toward understanding the topological insulators like bismuth selenide (Bi_2Se_3), bismuth telluride (Bi_2Te_3), antimony telluride (Sb_2Te_3), and mercury telluride (HgTe) that may have the potential to be the building blocks of a quantum computer, a machine with the potential of loading the information from a data center into the space of a laptop and processing data much faster than today's best supercomputers.

"The energy efficiency should be much better," said NREL Scientist Jun-Wei Luo, one of the co-authors. Instead of being confined to the on-and-off switches of the binary code, a quantum computer will act more like the human brain, seeing something but imagining much more, he said. "This is entirely different technology."

Topological Insulators are of great interest currently for their potential to use their exotic properties to transmit information on electron spins with virtually no expenditure of electricity, said Luo. NREL's Xiuwen Zhang is another co-author as are scientists from University of Colorado, Rutgers University, Brookhaven National Laboratory, Lawrence Berkeley National Laboratory, and the Colorado School of Mines. Luo and Zhang work in NREL's Center for Inverse Design, one of 46 Energy Frontier Research Centers established around the nation by the Energy Department's Office of Science in 2009 to accelerate basic research on energy.

The finding of orbital texture switch at Dirac point implies the novel backwards spin texture—right-handed instead of left-handed, in the short-hand of physicists—comes from the coupling of spin texture to the orbital texture for the conserved quantity is total angular momentum of the wave function, not spin. The new findings, supported partly by observations taken at the Advanced Light Source at Lawrence Berkeley National Laboratory, were surprising and bolster the potential of the topological insulators.

"In this paper, we computed and measured the profile of the topological states and found that the orbital texture of topological states switches from tangential to radial across the Dirac point," Zhang said. Equally surprising, they found that phenomenon wasn't a function of a unique material, but was common to all topological insulators.

The topological insulators probably won't be practical for solar cells, because at the surface they contain no band gap. A band gap – the gap between when a material is in a conducting state and an inert state – is essential for solar cells to free photons and have them turn into energy carrying electrons.

But the topological insulators could be very useful for other kinds of electronics-spintronics. The electrons of topological insulators will self-polarize at opposite device edges. "We usually drive the electron in a particular direction to spatially separate the spin-up and spin-down electrons, but this exotic property suggests that electrons as a group don't have to move," Luo said. "The initial idea is we don't need any current to polarize the electron spins. We may be able to develop a spin quantum computer and spin quantum computations."

In theory, an entire data center could operate with virtually no electricity. "That's probably more in theory than reality," Luo said, noting that other components of the center likely would still need electricity. "But it would be far more energy efficient." And the steep drop in electricity would also mean a steep drop in the number of coolers and fans needed to cool things down.

Luo cautioned that this is still basic science. The findings may have limited application to renewable energy, but Luo noted that another of NREL's key missions is energy efficiency.

More information: www.nature.com/nphys/journal/v … /full/nphys2685.html

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