

Spinning new theory on particle spin brings science closer to quantum computing

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Physicists at the U.S. Department of Energy's Argonne National Laboratory have devised a potentially groundbreaking theory demonstrating how to control the spin of particles without using superconducting magnets — a development that could advance the field of spintronics and bring scientists a step closer to quantum computing.

Spintronics, also known as spin electronics, is an emerging technology that looks to develop devices that exploit the quirky world of quantum physics, or physics at the incredibly small atomic level, particularly the up-or-down spin property of electrons. Conventional electronics use the charge of the electron. Spintronic devices would use both the spin and charge, achieving new functionality.

Scientists across the globe are racing to develop the spintronics field. It could revolutionize the computing industry with chips that are more versatile and exponentially more powerful than today's most cutting-edge technology.

Physicists Dimitrie Culcer and Roland Winkler, along with Christian Lechner of Regensburg University, Germany, will publish their theoretical findings in the Sept. 8 issue of *Physical Review Letters*. Culcer and Winkler are at Northern Illinois University, in addition to their affiliation with the Advanced Photon Source at Argonne.

“Our research illuminates a new pathway for generating and manipulating the spin in semiconductors,” Winkler said. “This is

important, because the use of bulky superconducting magnets would be impractical in most devices.”

The physicists theorize that spin can be induced and manipulated by running a current through gallium arsenide, a common semiconductor, in what is known as spin-3/2 hole systems, which previously have been little studied. Hole systems are “missing electrons,” while the fraction 3/2 refers to the magnitude of the spin. Spin-3/2 hole systems are created in semiconductors by “doping” — introducing impurities that have one less electron compared to the host material.

Geometry also must play a crucial role in spin manipulation, according to the researchers. They propose development of a nano-sized and L-shaped device that allows for the exploitation of the newly discovered effects in spin-3/2 hole systems.

“Spin polarization is achieved as the current flows around the corner,” Winkler said.

“We believe we've discovered a much simpler way for inducing spin polarization,” he added. “We don't need a big magnet. The only requirement in our case is an electrical current in the sample, which is much easier to achieve than putting the sample in a magnetic coil. For an electrical current, you only need two contacts.”

Culcer said the researchers hope the publication will raise awareness of new and exciting physics that can be accomplished in spin-3/2 hole systems.

“We do basic research and do not work directly on information technology,” Culcer said. “But researchers working on quantum computing are primarily interested in spin systems. For the past 50 years, scientists have intensely studied what's known as spin-1/2 systems.

“One of our primary goals with this paper was to demonstrate what could be accomplished with spin-3/2 systems,” he said. “We hope to point scientists in a direction that offers the possibility of new applications and hopefully ways of manipulating information in the future.”

Source: Argonne National Laboratory

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