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Spintronics advance brings wafer-scale quantum devices closer to reality

By
Carla Reiter (/taxonomy/term/49881)
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An electronics technology that uses the "spin"—or magnetization—of atomic nuclei to store and process information promises huge gains in performance over today's electron-based devices. But getting there is proving challenging.

Now, researchers at the University of Chicago's Institute for Molecular Engineering (https://ime.uchicago.edu/) have made a crucial step toward nuclear spintronic technologies. They have gotten nuclear spins to line themselves up in a consistent, controllable way, and they have done it using a high-performance material that is practical, convenient and inexpensive.

“Our results could lead to new technologies like ultra-sensitive magnetic resonance imaging, nuclear gyroscopes and even computers that harness quantum mechanical effects,” said Abram Falk, the lead author of the report on the research, which was featured as the cover article of the June 17 issue of Physical Review Letters (http://journals.aps.org/prl/abstract/10.1103/PhysRevLett.114.247603). Falk and colleagues in David Awschalom’s IME research group invented a new technique that uses infrared light to align spins. They did so using silicon carbide, an industrially important semiconductor.

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Nuclear spins tend to be randomly oriented. Aligning them in a controllable fashion is usually a complicated and only marginally successful proposition. The reason, explains Paul Klimov, a co-author of the paper, is that “the magnetic moment of each nucleus is tiny, roughly 1,000 times smaller than that of an electron.”

This small magnetic moment means that little thermal kicks from surrounding atoms or electrons can easily randomize the direction of the nuclear spins. Extreme experimental conditions such as high magnetic fields and cryogenic temperatures (-238 degrees Fahrenehit and below) are usually required to get even a small number of spins to line up. In magnetic resonance imaging, for example, only one to 10 out of a million nuclear spins can be aligned and seen in the image, even with a high magnetic field applied.

Using their new technique, Awschalom, the Liew Family Professor in Spintronics and Quantum Information, and his associates aligned more than 99 percent of spins in certain nuclei in silicon carbide. Equally important, the technique works at room temperature—no cryogenics or intense magnetic fields needed. Instead, the research team used light to “cool” the nuclei.