Electron spins controlled using sound waves

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The ability to control the intrinsic angular momentum of individual electrons – their "spins" – could lead to a world of new technologies that involve storing and processing information.

Cornell applied physicists have demonstrated an unprecedented method of control over electron spins using extremely high-frequency sound waves. A research team led by Greg Fuchs, assistant professor of applied and engineering physics, previously had demonstrated electron spin control using a mechanical oscillator, which creates gigahertz-frequency sound waves (audible in the kilohertz range).

According to a new paper published March 5 by the Optical Society's new journal *Optica*, they've taken it a step further: They not only created spin transitions with sound, but they also used sound to coherently control the quantum state of the spin. As the driven mechanical oscillator interacts with the electron spins inside, energy flows back and forth in between. This marks a huge step forward in understanding electron spin.

Electron spins typically are controlled by applying a magnetic field to flip the spins up or down – the same way nuclear spins are influenced in magnetic resonance imaging technology. But Fuchs' group flips the spins a different way: They use sound waves from a resonator made out of a diamond. In particular, they study electron spins stored in defects in the diamond crystal called nitrogen-vacancy centers, the study of which is a promising platform for the growing field of spintronics.

"A big part of what our group does is to figure out what all the knobs are and how we turn them," Fuchs said.

Here's another way of looking at the accomplishment: Electron spin is a quantum phenomenon – something that happens at the atomic scale. Fuchs' group demonstrates control of a quantum phenomenon using classical vibrations. It's like reaching through a portal between two branches of physics, exerting force from one side to control something just on the other side.

"We're coherently interacting this quantum thing, this spin, with something that's big and mechanical, a thing you can see with your naked eye, and that actually vibrates," Fuchs said.

The resonator is on the scale of hundreds of microns – easily visible. The acoustical vibrations are the same things that cause a wine glass to break in response to a high note.

So what's this good for? At the moment, the researchers are still working out all the physics. But some of the technologies mechanical spin control could lead to include magnetic field sensing, inertial motion sensing and quantum information processing.

The paper is called "Coherent Control of Nitrogen-Vacancy Center Spin Ensemble With a Diamond Mechanical Resonator," and its first author is Evan MacQuarrie, a graduate student in Fuchs' lab. As with the previous work, Fuchs' group collaborated with Sunil Bhave, associate professor of electrical and computer engineering, and his graduate student Tanay Gosavi.

More information: "Coherent control of a nitrogen-vacancy center spin ensemble with a diamond mechanical resonator." *Optica*, Vol. 2, Issue 3, pp. 233-238 (2015) dx.doi.org/10.1364/OPTICA.2.000233

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