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Quantum state of single electrons controlled by 'surfing' on sound waves

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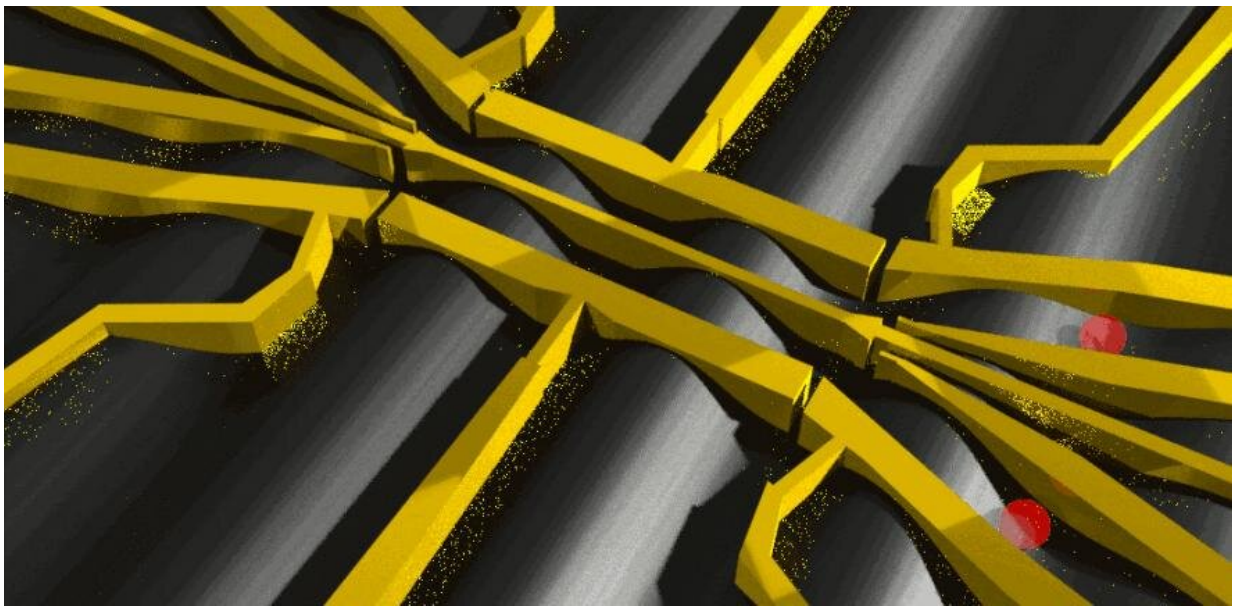

Credit: University of Cambridge

Researchers have successfully used sound waves to control quantum information in a single electron, a significant step towards efficient, robust quantum computers made from semiconductors.

The international team, including researchers from the University of Cambridge, sent high-frequency sound waves across a modified semiconductor device to direct the behaviour of a single electron, with efficiencies in excess of 99 percent. The results are reported in the journal *Nature Communications*.

A quantum computer would be able to solve previously unsolvable computational problems by taking advantage of the strange behaviour of particles at the subatomic scale, and quantum phenomena such as entanglement and superposition. However, precisely controlling the behaviour of quantum particles is a mammoth task.

"What would make a quantum computer so powerful is its ability to scale exponentially," said co-author Hugo Lepage, a Ph.D. candidate in Cambridge's Cavendish Laboratory, who performed the theoretical work for the current study. "In a classical computer, to double the amount of information you have to double the number of bits. But in a quantum computer, you'd only need to add one more quantum bit, or qubit, to double the information."

Last month, researchers from Google claimed to have reached 'quantum supremacy', the point at which a quantum computer can perform calculations beyond the capacity of the most powerful supercomputers. However, the quantum computers which Google, IBM and others are developing are based on superconducting loops, which are complex circuits and, like all quantum systems, are highly fragile.

"The smallest fluctuation or deviation will corrupt the quantum information contained in the phases and currents of the loops," said Lepage. "This is still very new technology and expansion beyond the intermediate scale may require us to go down to the single particle level."

Instead of superconducting loops, the quantum information in the quantum computer Lepage and his colleagues are devising use the 'spin' of an electron—its inherent angular momentum, which can be up or down—to store quantum information.

"Harnessing spin to power a functioning quantum computer is a more scalable approach than using superconductivity, and we believe that using spin could lead to a quantum computer which is far more robust, since spin interactions are set by the laws of nature," said Lepage.

Using spin allows the quantum information to be more easily integrated with existing systems. The device developed in the current work is based on widely-used semiconductors with some minor modifications.

The device, which was tested experimentally by Lepage's co-authors from the Institut Néel, measures just a few millionths of a metre long. The researchers laid metallic gates over a semiconductor and applied a voltage, which generated a complex electric field. The researchers then directed high-frequency sound waves over the device, causing it to vibrate and distort, like a tiny earthquake. As the sound waves propagate, they trap the electrons, pushing them through the device in a very precise way, as if the electrons are 'surfing' on the sound waves.

The researchers were able to control the behaviour of a single electron with 99.5 percent efficiency. "To control a single electron in this way is already difficult, but to get to a point where we can have a working quantum computer, we need to be able to control multiple electrons, which get exponentially more difficult as the qubits start to interact with each other," said Lepage.

In the coming months, the researchers will begin testing the device with multiple electrons, which would bring a working quantum computer another step closer.

More information: Shintaro Takada et al. Sound-driven single-electron transfer in a circuit of coupled quantum rails, *Nature*

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