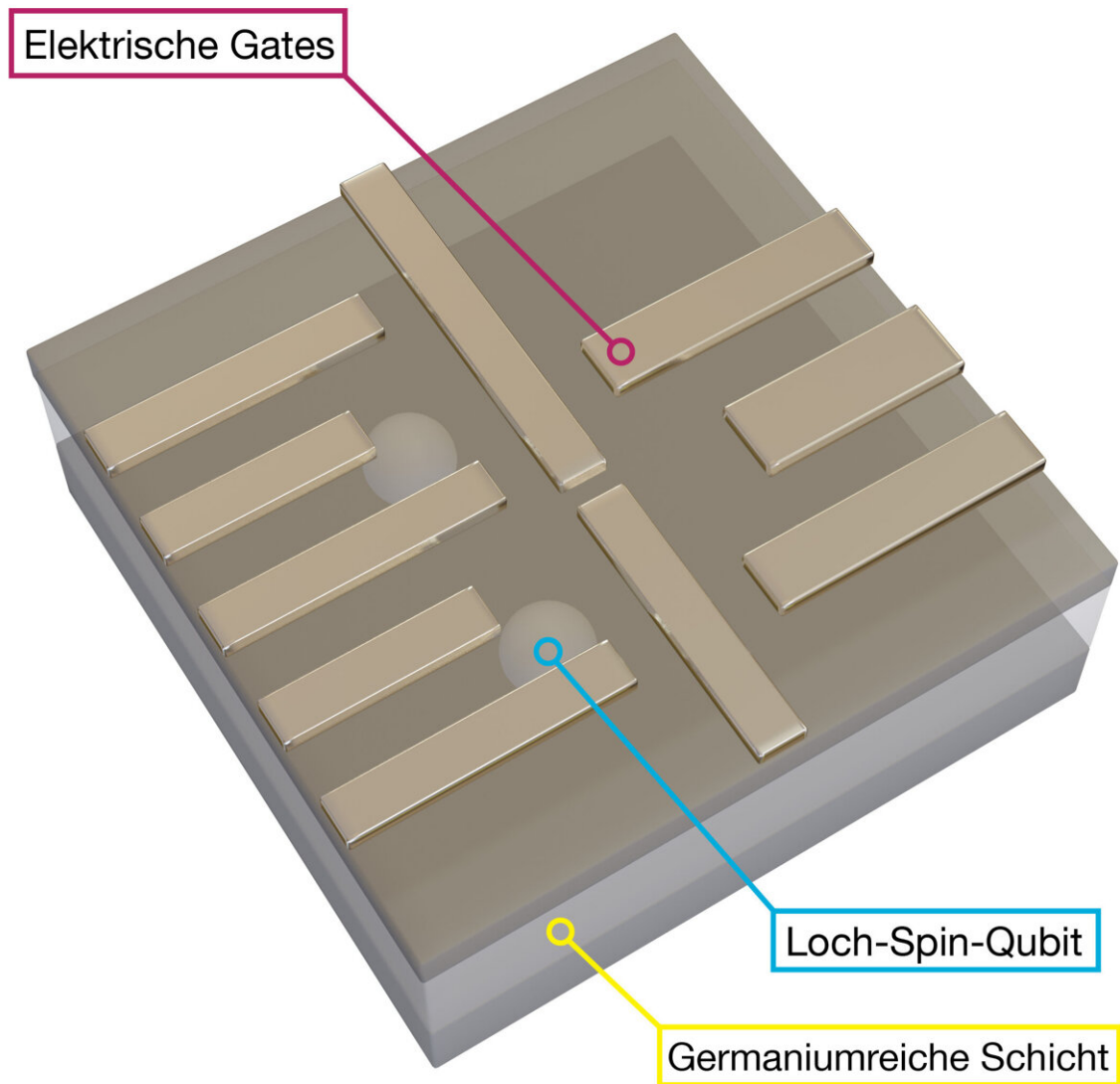


Quantum computing with holes

June 3 2021



The two holes are confined to the germanium-rich layer just a few nanometers

thick. On top, the electrical gates are formed by individual wires with voltages applied. The positively charged holes feel the push and pull from the wires and can therefore be moved around within their layer. Credit: Daniel Jirovec

Quantum computers, with their promises of creating new materials and solving intractable mathematical problems, are a dream of many physicists. Now, they are slowly approaching viable realization in many laboratories all over the world. But there are still enormous challenges to master. A central one is the construction of stable quantum bits—the fundamental unit of quantum computation, called "qubit" for short—that can be networked together.

In a study published in *Nature Materials* and led by Daniel Jirovec from the Katsaros group at IST Austria in close collaboration with researchers from the L-NESS Inter-university Center in Como, Italy, scientists now have created a new and promising candidate system for reliable qubits.

Spinning Absence

The researchers created the qubit using the spin of so-called [holes](#). Each hole is simply the absence of an electron in a [solid material](#). Amazingly, a missing, negatively charged particle can physically be treated as if it were a positively charged particle. It can even move around in the solid when a neighboring electron fills the hole. Thus, effectively, the hole described as positively charged particle is moving forward.

These holes even carry the quantum-mechanical property of spin and can interact if they come close to each other. "Our colleagues at L-NESS layered several different mixtures of silicon and germanium just a few nanometers thick on top of each other. That allows us to confine the holes to the germanium-rich layer in the middle," Jirovec explains. "On

top, we added tiny electrical wires—so-called gates—to control the movement of holes by applying voltage to them. The electrically positively charged holes react to the voltage and can be extremely precisely moved around within their layer."

Using this nano-scale control, the scientists moved two holes close to each other to create a qubit out of their interacting spins. But to make this work, they needed to apply a magnetic field to the whole setup. Here, their innovative approach comes into play.

Linking Qubits

In their setup, Jirovec and his colleagues cannot only move holes around but also alter their properties. By engineering different hole properties, they created the qubit out of the two interacting hole spins using less than ten millitesla of magnetic field strength. This is a weak magnetic field compared to other similar qubit setups, which employ at least ten times stronger fields.

But why is that relevant? "By using our layered germanium setup we can reduce the required [magnetic field](#) strength and therefore allow the combination of our [qubit](#) with superconductors, usually inhibited by strong magnetic fields," Jirovec says. Superconductors—materials without any electrical resistance—support the linking of several qubits due to their quantum-mechanical nature. This could enable scientists to build new kinds of quantum computers combining semiconductors and superconductors.

In addition to the new technical possibilities, these hole spin qubits look promising because of their processing speed. With up to one hundred million operations per second as well as their long lifetime of up to 150 microseconds they seem particularly viable for [quantum computing](#). Usually, there is a tradeoff between these properties, but this new design

brings both advantages together.

More information: A singlet-triplet hole spin qubit in planar Ge, *Nature Materials* (2021). [DOI: 10.1038/s41563-021-01022-2](https://doi.org/10.1038/s41563-021-01022-2) , www.nature.com/articles/s41563-021-01022-2

Provided by Institute of Science and Technology Austria

Citation: Quantum computing with holes (2021, June 3) retrieved 25 April 2024 from <https://phys.org/news/2021-06-quantum-holes.html>

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