Quantum computing: Cold chips can control qubits

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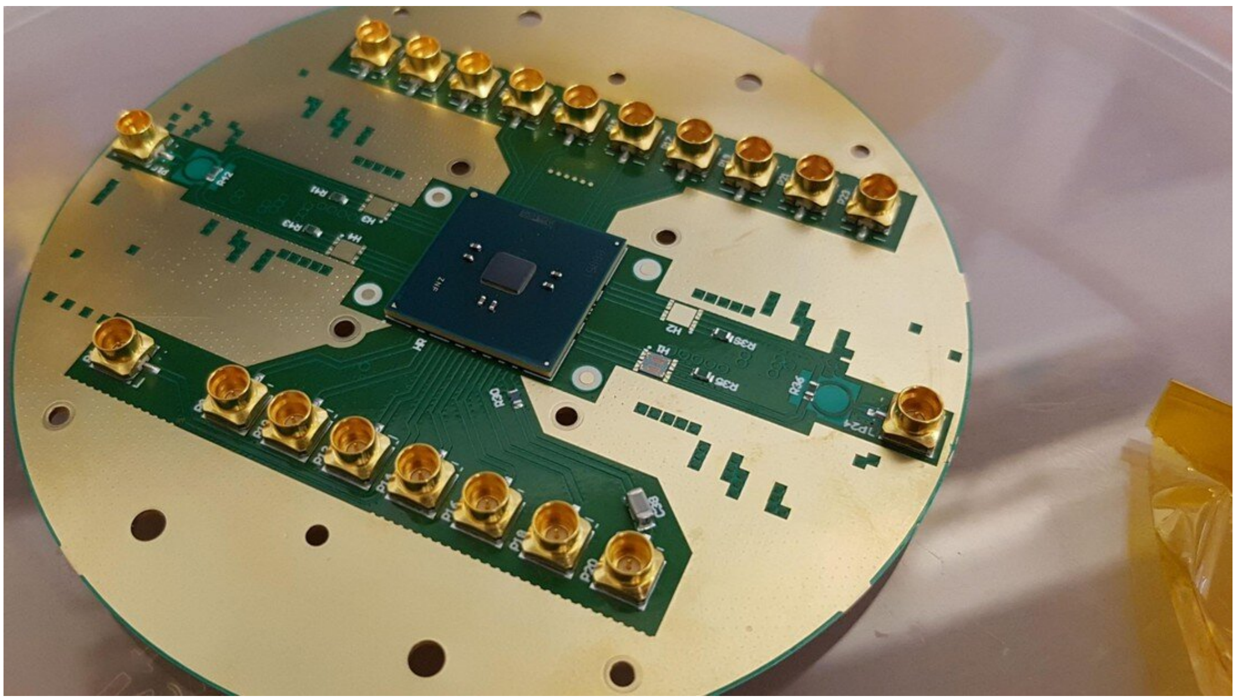

Credit: Ecole Polytechnique Federale de Lausanne

Researchers and engineers from QuTech in the Netherlands and from Intel Corp., jointly designed and tested a chip to control qubits that can operate at extremely low temperatures, and opens the door to solving the "wiring bottleneck," an important step toward a scalable quantum computer. Their results are published in the scientific journal *Nature*.

Each basic unit of a quantum computer, a qubit, is typically addressed individually by a single wire. "This stands in the way of a scalable quantum computer, since millions of qubits would require millions of wires' explains lead investigator Lieven Vandersypen from QuTech. "This is called the 'wiring bottleneck." In traditional computers a modern processor with billions of transistors has only a few thousand connections. The cryogenic temperatures at which qubits operate (20 millikelvin, or about -273 degrees Celsius) complicate the use of traditional solutions." Such a chip could simply not endure the extreme temperatures, so a new cryogenic control chip has been designed and tested.

Intel Horse Ridge

Engineers at Intel and QuTech—a collaboration between Delft University of Technology and TNO, the Netherlands Organization for applied scientific research—designed a special silicon-based integrated circuit able to withstand the cold (3 degrees Celsius above absolute zero) and also address qubits. The so-called "Horse Ridge' chip is named after the coldest place in Oregon, the state where the Intel lab resides.

"We exploited the same technology adopted for the conventional microprocessor, the CMOS technology. For Horse Ridge, we specifically used the Intel 22nm low-power FinFET technology." said co-lead investigator Edoardo Charbon, head of EPFL's Advanced Quantum Architecture Laboratory. "As electronic devices operate very differently at cryogenic temperatures, we used special techniques in the chip design both to ensure the right operation and to drive qubits with high accuracy." Ultimately controller chip and qubits can be integrated on the same die (as they are all fabricated in silicon) or package, thus further relieving the wiring bottleneck.

High fidelity and good programmability

To assess the quality of the cryogenic Horse Ridge control chip it was compared with a classical room temperature controller. It turns out the gate fidelity of the system is very high (99.7%) and limited not by the controller but by the qubits themselves. That's great news for the performance of the cryogenic control chip.

Next, the programmability of the controller was showcased using a two-qubit quantum algorithm. The Deutsch–Jozsa algorithm is one of the simplest algorithms that is much more efficient on a quantum computer than a traditional computer. This demonstrates the ability to program the control chip with arbitrary sequences of operations, and opens the way to on-chip implementation and a truly scalable quantum computer.

More information: Xiao Xue et al. CMOS-based cryogenic control of silicon quantum circuits, *Nature* (2021). DOI: 10.1038/s41586-021-03469-4

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