Google Plans to Demonstrate the Supremacy of Quantum Computing

By the end of 2017, Google hopes to make a 49-qubit chip that will prove quantum computers can beat classical machines

By **RACHEL COURTLAND (/AUTHOR/COURTLAND-RACHEL)** Posted 24 May 2017 | 15:00 GMT

Quantum computers have long held the promise of performing certain calculations that are impossible—or at least, entirely impractical—for even the most powerful conventional computers to perform. Now, researchers at a Google laboratory in Goleta, Calif., may finally be on the cusp of proving it, using the same kinds of quantum bits, or qubits, that one day could make up large-scale quantum machines.

By the end of this year, the team aims to increase the number of superconducting qubits (http://spectrum.ieee.org/tag/qubit) it builds on integrated circuits to create a 7-by-7 array. With this quantum IC, the Google researchers aim to perform operations at the edge of what's possible with even the best supercomputers, and so demonstrate "quantum supremacy."

"We've been talking about, for many years now, how a quantum processor could be powerful because of the way that quantum mechanics works, but we want to specifically demonstrate it," says team member John Martinis (http://web.physics.ucsb.edu

/~martinisgroup/), a professor at the University of California, Santa Barbara, who joined Google in 2014.

A system size of 49 superconducting qubits is still far away from what physicists think will be needed to perform the sorts of computations that have long motivated quantum computing research. One of those is Shor's algorithm, a computational scheme that would enable a quantum computer to quickly factor very large numbers and thus crack one of the foundational components of modern cryptography. In a recent commentary in *Nature*, Martinis and colleagues estimated that a 100-million-qubit system would be needed to factor a 2,000-bit number—a not-uncommon public key length—in one day. Most of those qubits would be used to create the special quantum states that would be needed to perform the computation and to correct errors, creating a mere thousand or so stable "logical qubits" from thousands of less stable physical components, Martinis says.

There will be no such extra infrastructure in this 49-qubit system, which means a different computation must be performed to establish supremacy. To demonstrate the chip's superiority over conventional computers, the Google team will execute operations on the array that will cause it to evolve chaotically and produce what looks like a random output. Classical machines can simulate this output for smaller systems. In April, for example, Lawrence Berkeley National Laboratory reported that its 29-petaflop supercomputer (https://www.top500.org/news/berkeley-lab-supercomputer-breaks-new-ground-in-quantum-computing-simulation/), Cori, had simulated the output of 45 qubits. But 49 qubits would push—if not exceed—the limits of conventional supercomputers.

This computation does not as yet have a clear practical application. But Martinis says there are reasons beyond demonstrating quantum supremacy to pursue this approach. The qubits used to make the

49-qubit array can also be used to make larger "universal" quantum systems with error correction, the sort that could do things like decryption, so the chip should provide useful validation data.

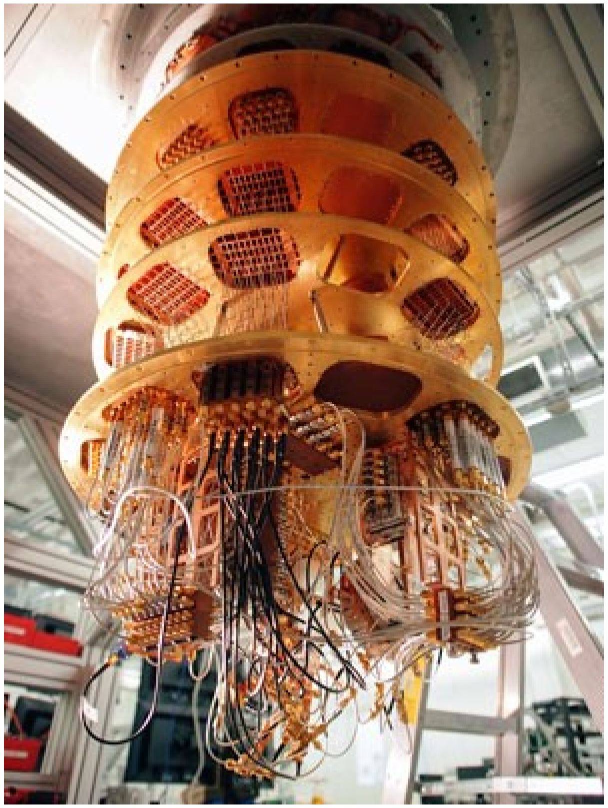

Photo: Erik Lucero

Put Chip Here: Google will put its superconducting quantum computer chip in this 10-millikelvin dilution refrigerator.

There may also be, the team suspects, untapped computational potential in systems with little or no error correction. "It would be wonderful if this were true, because then we could have useful products right away instead of waiting for a long time," says Martinis. One potential application, the team suggests, could be in the simulation of chemical reactions and materials.

Google recently performed a dry run of the approach on a 9-by-1 array of qubits and tested out some fabrication technology on a 2-by-3 array. Scaling up the number of qubits will happen in stages. "This is a challenging system engineering problem," Martinis says. "We have to scale it up, but the qubits still have to work well. We can't have any loss in fidelity, any increase in error rates, and I would say error rates and scaling tend to kind of compete against each other." Still, he says, the team thinks there could be a way to scale up systems well past 50 qubits even without error correction.

Google is not the only company working on building larger quantum systems without error correction. In March, IBM unveiled a plan (http://spectrum.ieee.org/tech-talk/computing/hardware/ibm-expanding-cloud-quantum-computer-10fold) to create such a superconducting qubit system in the next few years, also with roughly 50 qubits, and to make it accessible on the cloud. "Fifty is a magic number," says Bob Sutor, IBM's vice president for this area, because that's around the point where quantum computers (http://spectrum.ieee.org/tag/quantum+computers) will start to outstrip classical computers for certain tasks.

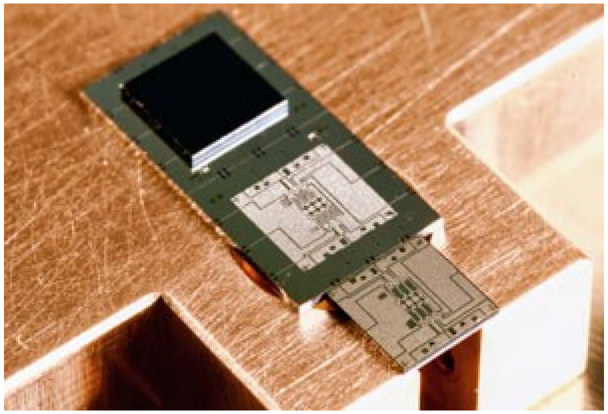

Photo: Erik Lucero

Steps to Supremacy: Google's quantum computing chip is a 2-by-3 array of qubits. The company hopes to make a 7-by-7 array later this year.

The quality of superconducting qubits has advanced a lot over the years since D-Wave Systems began offering commercial quantum computers, says Scott Aaronson (http://www.scottaaronson.com/), a professor of computer science at the University of Texas at Austin. D-Wave, based in Burnaby, B.C., Canada, has claimed that its systems offer a speedup over conventional machines, but Aaronson says there has been no convincing demonstration of that. Google, he says, is clearly aiming for a demonstration of quantum supremacy that is "not something you'll have to squint and argue about."

It's still unclear whether there are useful tasks a 50-or-so-qubit chip could perform, Aaronson says. Nor is it certain whether systems can be made bigger without error correction. But he says quantum supremacy will be an important milestone nonetheless, one that is a natural offshoot of the effort to make large-scale, universal quantum machines: "I think that it is absolutely worth just establishing as clearly as we can that the world does work this way. Certainly, if we can do it as a spin-off of technology that will be useful eventually in its own right, then why the hell not?"

This article appears in the June 2017 print issue as "Google Aims for Quantum Computing Supremacy."

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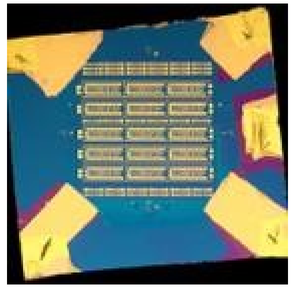

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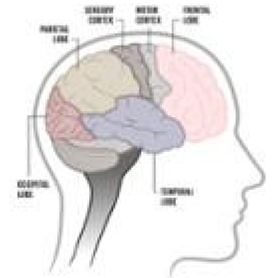

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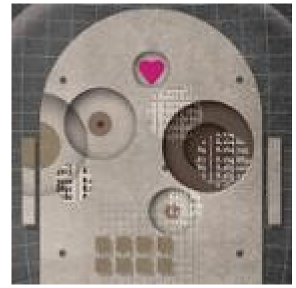

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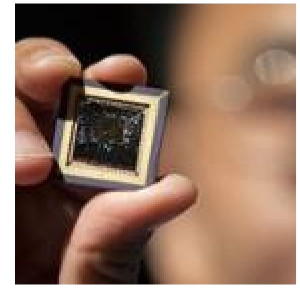

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