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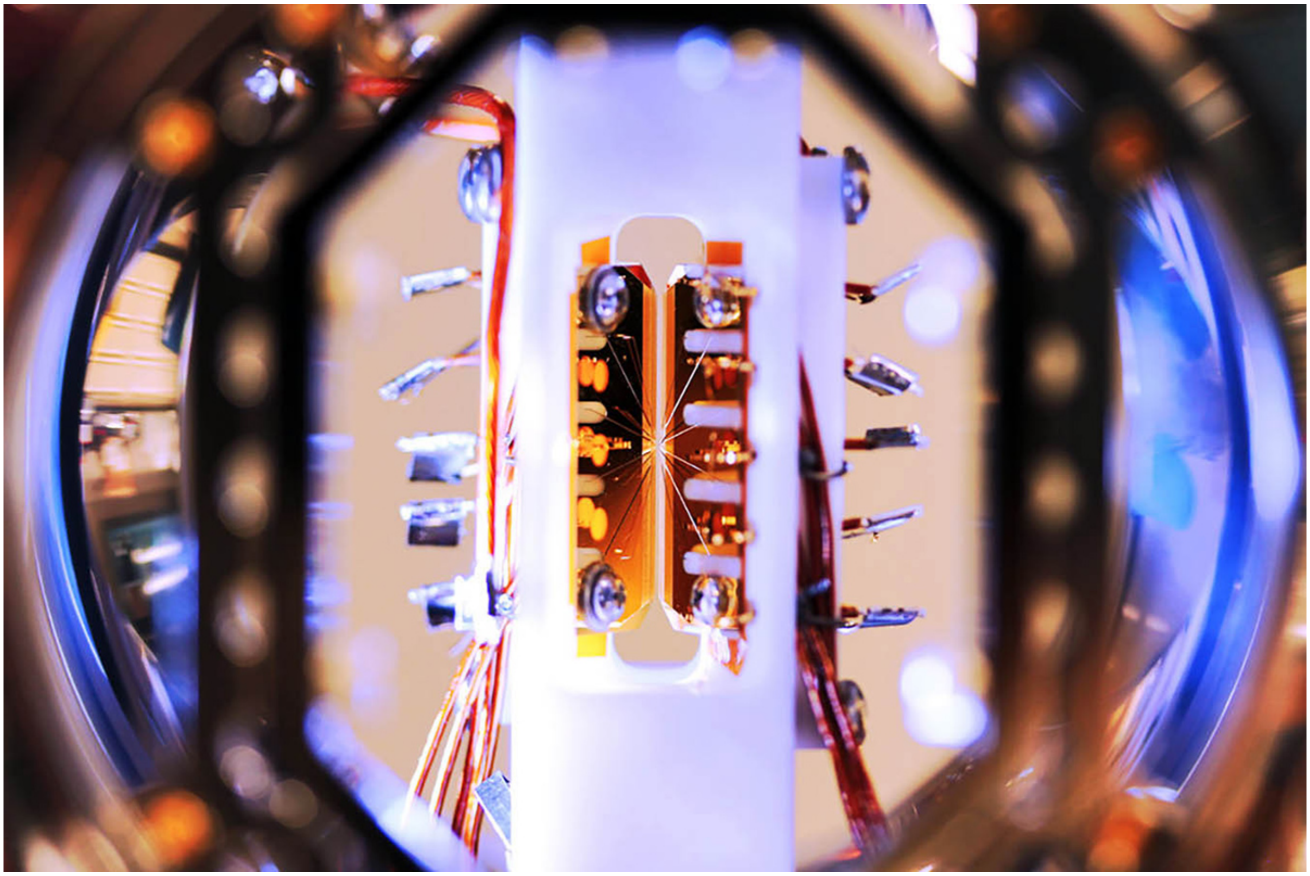
Best-yet quantum simulator with 53 qubits could really be useful



Trapped ions are closer to doing our quantum calculations
University of Maryland

By **Mark Kim**

We're two qubits closer to useful quantum computers. That might not sound like much, but in the quantum computing arms race, several groups are edging past one another as they aim to eventually make a universal quantum computer.

A group of researchers at the Joint Quantum Institute has created a quantum simulator using 53 quantum bits, or qubits. Earlier this month, IBM announced a 50-qubit prototype, though its capabilities are unclear.

With this 53-qubit device, the researchers have done scientific simulations that don't seem to be possible with classical computers. The design for this simulator could lead to a true quantum computer one day.

Most quantum simulators are built to run one specific program, but the team thinks it should be possible to tweak their device to run multiple programs, rather than having to build a separate simulator for each program.

"This is real quantum hardware. This can be turned into a quantum computer without much changing," says Christopher Monroe at the University of Maryland, whose group built the 53-qubit simulator out of a chain of charged atoms trapped in electric fields.

Mikhail Lukin at Harvard University, whose own group announced the completion of a 51-qubit simulator built on neutral atoms back in July, is keen to point out that "there's nothing special about 51 atoms or 53 atoms." He says his team chose their goal with IBM in mind. "We just wanted an odd number of atoms and 51 was the smallest number above 50."

Scaling up

Lukin offers three ways to measure the quality of a quantum computing device: number of qubits, coherence and programmability. More qubits means larger-scale computations. Better coherence means more trustworthy results. Higher programmability means wider utility. Ideally, we want them all.

He thinks that his team's device and Monroe's could go bigger: "Both simulators can certainly scale to about 100 qubits."

Daniel Lidar at the University of Southern California agrees that the simulators are "scalable to 100 qubits or more". But he points out this will require arranging atoms in a two-dimensional grid, as the performance of a chain of ions degrades as it gets longer. The two-dimensional arrangement is tricky to achieve, because it requires extremely precise control of the ion positions. It may even require specially designed ions that can quench excess motion.

Monroe's group, and Lukin's as well, used qubits made of atoms that are carefully separated with ion traps to prevent unintended interactions between them that can lead to errors.

In contrast, Google, IBM and Intel employ superconducting electronic circuits to build their quantum computers. No two circuits are identical, because you can't build them to be exactly the same in terms of their atomic compositions. "Atoms are identical, and that's a fundamental scaling advantage that no solid-state system will ever have," says Monroe.

Putting qubits to work

The quantum simulators in Monroe and Lukin's groups focus on the number of qubits and coherence. The different choices of atoms the two groups have made affect these two qualities. "It's easier to have a larger array of neutral atoms, since they won't repel, and each can be trapped more easily," says Lukin. On the other hand, ion traps are more coherent, resulting in lower error rates in computation.

While these quantum simulators aren't full-blown quantum computers, they have already played an important role in the two groups' research.

"We are entering an interesting era where we actually use quantum machines for useful tasks," says Lukin. Quantum simulators, and their eventual successors – quantum computers – can be used to simulate interactions in complex systems, such as the relationships between molecules in the body, or how matter behaved at the beginning of the universe.

For now, Lukin's group have used their simulator to discover a rare non-equilibrium state of a complex many-particle system that has not been predicted theoretically. Monroe's group used their simulator to study the symmetry-breaking phenomenon in quantum systems at a scale larger than what most, if not all, classical computers can handle.

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