IBM, Rigetti, MIT, Microsoft & others taking big strides in building large scale programmable quantum computers

Quantum computing and quantum information processing are next revolutionary technology expected to have immense impact. Quantum computers will be able to perform tasks too hard for even the most powerful conventional supercomputer and have a host of specific applications, from code-breaking and cyber security to medical diagnostics, big data analysis and logistics. Quantum computers could accelerate the discovery of new materials, chemicals and drugs. They could dramatically reduce the current high costs and long lead times involved in developing new drugs.

Many groups are at the threshold of producing scalable quantum computers. The leader of Google's quantum computing lab, has predicted that it can build chips with about 100 reliable qubits in a couple of years. Its group has built a nine-qubit machine based on tiny, superconducting circuits and hopes to scale up to 49 within a year—an important threshold.

Researchers at D-Wave, IBM, MIT Lincoln Lab, and elsewhere have also developed superconducting qubits of high quality.

At the IEEE Industry Summit on the Future of Computing in Washington D.C. in Oct 2017, IBM announced the development of a quantum computer capable of handling 50 qubits (quantum bits) so far the largest and most powerful quantum computer ever built. At about 50 qubits, many say a quantum computer could achieve "quantum supremacy," a term coined by John

Preskill, a physicist at the California Institute of Technology in Pasadena, to denote a quantum computer that can do something beyond the ken of a classical computer, such as simulate molecular structures in chemistry and materials science, or tackle certain problems in cryptography or machine learning.

Rigetti is also making the new quantum computer—which can handle 19 quantum bits, or qubits—available through its cloud computing platform, called Forest.

Now Microsoft has also doubled down on quantum computing bet. “People are really building things,” says Christopher Monroe, a physicist at the University of Maryland in College Park who co-founded the start-up IonQ in 2015. “I’ve never seen anything like that. It’s no longer just research.”

Canadian firm D-Wave has released the new quantum computer that will be able to handle some 2,000 quantum bits (qubits), roughly double the usable number found in the processor in the existing D-Wave 2X system, and be capable of solving certain problems 1,000x faster than its predecessor.

However, D-Wave is not a universal quantum computer, it has been designed specifically to perform a process called “quantum annealing”, which is a technique for finding the global minimum of some complicated mathematical expressions hence expected to be capable of solving optimization and sorting problems exponentially faster than a classical computer.

Quantum Computer Approaches

There have been two leading approaches for building general purpose Quantum computer. One approach, adopted by Google, IBM, Rigetti and Quantum Circuits involves encoding quantum states as oscillating currents in superconducting loops. The other, pursued by IonQ and several major academic labs, is to encode qubits in single ions held by electric and magnetic fields in vacuum traps.

Recently, researchers at Cornell University pitted two quantum computers against each other in an epic virtual battle. The challenge was to perform and solve an algorithm to compare and determine which quantum computer is the most effective. Both computers are state-of-the-art 5-qubit quantum computers which operate on two entirely different platforms.

“Recently, two architectures, superconducting transmon qubits and trapped ions, have reached a new level of maturity. They have become fully programmable multi-qubit machines that provide the user with the flexibility to implement arbitrary quantum circuits from a high-level interface. This makes it possible for the first time to test quantum computers irrespective of their particular physical implementation,” write N. M. Linke and others.

Despite their differences, the researchers discovered a way to program the computers in such a way that is blind to the operating hardware. The results determined one computer was more reliable, and the other could carry out operations faster.

“For a long time, the devices were so immature that you couldn’t really put two five-qubit gadgets next to each other and perform this kind of comparison,” says Simon Benjamin, a physicist at the University of Oxford in the United Kingdom, who is not affiliated with the study. “It’s a sign that this technology is maturing.” In addition, the results suggest that co-designing particular quantum applications with the hardware itself will be paramount in successfully using quantum computers in the future.

Quantum computing making big strides

The startup Rigetti Computing is trying to build the hardware needed to power a quantum computer. The company aims to produce a prototype chip by the end of 2017 that is significantly more complex than those built by other groups working on fully programmable quantum computers. The following generation of chips should be able to accelerate some kinds of machine learning and run highly accurate chemistry simulations that might unlock new kinds of industrial processes, says Chad Rigetti, the startup's founder and CEO. It is also working on software to make it easy for other companies to write code for its quantum hardware.

Rigetti says his company has worked out a qubit design that should be stable enough to scale up, and that can be made using conventional chip-manufacturing techniques. The startup is currently testing a three-qubit chip made using aluminum circuits on a silicon wafer, and the design due next year should have 40 qubits.

IBM's five qubit general purpose quantum computer based on superconducting atoms

In analogy to atoms given by nature, the man-made superconducting circuits in the IBM quantum computer can be thought of as "artificial atoms" . They are transmon qubits , or superconducting islands connected by Josephson junctions and shunt capacitors that provide superpositions of charge states which are insensitive to charge fluctuations.

The device used here has a range of qubit frequencies between 5 and 5.4 GHz. The qubits are connected to each other and the classical control system by microwave resonators. State preparation and readout, as well as single- and two qubit gates , are achieved by applying tailored microwave signals to this network and measuring the response. Qubits are resolved in the frequency domain during addressing and readout. The publicly accessible system runs autonomously, not requiring any human intervention over many weeks.

“This is a very exciting time,” says Daniel Lidar, director of the Center for Quantum Information Science and Technology at the University of Southern California. “This is not incremental; we’re really starting to see various groups working with superconducting qubits taking big strides forward.” However, it is still far from clear when useful, large-scale quantum chips might be made, says Lidar. A serious attempt at building one remains an expensive undertaking, he says.

MIT Just Unveiled A Technique to Mass Produce Quantum Computers

Researchers have found a way to make the creation of qubits simpler and more precise. The team hopes that this new technique could, one day, allow for the mass production of quantum computers. Researchers from MIT, Harvard University, and Sandia National Laboratories unveiled a simpler way of using atomic-scale defects in diamond materials to build quantum computers in a way that could possibly allow them to be mass produced.

For this process, defects are they key. They are precisely and perfectly placed to function as qubits and hold information. Previous processes were difficult, complex, and not precise enough. This new method creates targeted defects in a much simpler manner. Experimentally, defects created were, on average, at or under 50 nanometers of the ideal locations.

The significance of this cannot be overstated. “The dream scenario in quantum information processing is to make an optical circuit to shuttle photonic qubits and then position a quantum memory wherever you need it," says Dirk Englund, an associate professor of electrical engineering and computer science, in an interview with MIT. "We're almost there with this. These emitters are almost perfect."

One of the main remaining hurdles is how these computers will read the qubits. But these diamond defects aim to solve that problem because they naturally emit light, and since the light particles emitted can retain superposition, they could help to transmit information.

The research goes on to detail how the completion of these diamond materials better allowed for the amplification of the qubit information. By the end, the researchers found that the light emitted was approximately 80-90 percent as bright as possible.

Five qubit fully programmable computer based on ions

Scientists have created the first programmable and reprogrammable quantum computer, according to a new study. The technology could usher in a much-anticipated era of quantum computing, which researchers say could help scientists run complex simulations and produce rapid solutions to tricky calculations.

"Until now, there hasn't been any quantum-computing platform that had the capability to program new algorithms into their system. They're usually each tailored to attack a particular algorithm," said study lead author Shantanu Debnath, a quantum physicist and optical engineer at the University of Maryland, College Park.

Now, Debnath and his colleagues have developed the first fully programmable and reprogrammable quantum computer. The new device is made of five qubits. Each qubit is an ion, or electrically charged particle, trapped in a magnetic field.

It consists of five ytterbium ions lined up and trapped in an electromagnetic field. The electronic state of each ion can be controlled by zapping it with a laser. This allows each ion to store a bit of quantum information.

The scientists can use lasers to manipulate these ions – five ytterbium atoms – infusing them with precise amounts of energy and influencing their interactions with each other. Because they are charged, the ions exert a force on each other, and this causes them to vibrate at frequencies that can be precisely controlled and manipulated. These vibrations are quantum in nature and allow the ions to become entangled. In this way, the quantum bits they hold can interact.

By controlling these interactions, physicists can carry out quantum logic operations. And quantum algorithms are simply a series of these logic operations one after the other. In this way, the researchers can program and reprogram the quantum computer with a variety of algorithms.

The researchers tested their device on three algorithms that quantum computers, as prior work showed, could execute quickly. One, the so-called Deutsch-Jozsa algorithm, is typically used only for tests of quantum-computing capabilities. Another, the Bernstein-Vazirani algorithm, can also be used to probe for errors in quantum computing. The last, the quantum Fourier transform algorithm, is an element in quantum-computing encryption-breaking applications.

The Deutsch-Jozsa and Bernstein-Vazirani algorithms successfully ran 95 and 90 percent of the time, respectively. The quantum Fourier transform algorithm, which the researchers said is among the most complicated quantum calculations, had a 70 percent success rate, they said.

In the future, the researchers will test more algorithms on their device, Debnath said. “We’d like this system to serve as a test bed for examining the challenges of multiqubit operations, and find ways to make them better,” Debnath told Live Science.

The team claims it can go much further. In particular, they say that their module is scalable—that several five-qubit modules can be connected together to form a much more powerful quantum computer.

Japanese boffins try ‘token passing’ to scale quantum calculations

A Japanese team has published what it believes is a solution to the problem of scale. Quantum gates are complex creatures with many more components than their classical equivalents, so instead of trying to cram enough gates into a small space to perform calculations, the University of Tokyo proposal is to send photons around in a ring, re-using one gate to act on different photons in turn.

If need be, the light pulses can travel around the loop indefinitely, according to professor Akira Furusawa and assistant professor Shuntaro Takeda, who came up with the scheme, without losing the quantum information they carry.

Because of this, the pair make a fairly bold claim: “This approach potentially enables scalable, universal, and fault tolerant quantum computing, which is hard to achieve by either qubit or CV [continuous variable – El Reg] scheme alone.”

The paper, published at Physical Review Letters and also available at arXiv (PDF), also notes that the scheme is compatible with existing quantum error-correction techniques. In a media release (here) Professor Furusawa says his team is working on automating the error-correction process. The release adds that his previous optical-based quantum computing system needed 6.3m2 and 500 mirrors and lenses, and could only handle a single pulse at a time.

Furusawa's paper notes that the gate sequence is electrically programmed, making it fast, and it notes that "all the basic building blocks of our architecture are already available", meaning the work should be replicable. Furusawa said in the canned statement: "We'll start work to develop the hardware, now that we've resolved all problems except how to make a scheme that automatically corrects a calculation error."

Construction of large scale practical quantum computers radically simplified

While Quantum computing on a small scale using trapped ions (charged atoms) can be carried out by aligning individual laser beams onto individual ions with each ion forming a quantum bit. However, a large-scale quantum computer would need billions of quantum bits, therefore requiring billions of precisely aligned lasers, one for each ion.

Instead, scientists at Sussex have invented a simple method where voltages are applied to a quantum computer microchip (without having to align laser beams) – to the same effect. Professor Winfried Hensinger and his team also succeeded in demonstrating the core building block of this new method with an impressively low error rate at their quantum computing facility at Sussex.

"We've reduced the difficulty of building a quantum computer to the equivalent of building a classical computer. In a classical computer, you have transistors and they apply voltage to execute a classical logic gate," Winfried Hensinger, professor of quantum technologies at the University of Sussex's Ion Quantum Technology Group, told IBTimes UK.

"We use microwave radiation, bathe the entire quantum computer in microwaves, then we have local magnetic field gradients within the actual processing zones, and by applying a voltage, we shift the position of the ion so it either interacts with the global microwaves or not."

Professor Hensinger said: "This development is a game changer for quantum computing making it accessible for industrial and government use. We will construct a large-scale quantum computer at Sussex making full use of this exciting new technology."

Microsoft building quantum computer based on topological qubit

Researchers at Microsoft are working on an entirely new topological quantum computer, which uses exotic materials to limit errors. Microsoft's new hires include Leo Kouwenhoven, a professor at the Delft University of Technology in the Netherlands; Charles Marcus, a professor at the University of Copenhagen; Matthias Troyer, a professor at ETH Zurich; and David Reilly, a professor at the University of Sydney in Australia.

Microsoft's approach to building a quantum computer is based on a type of qubit – or unit of quantum information – called a topological qubit. The Microsoft team believes that topological qubits are better able to withstand challenges such as heat or electrical noise, allowing them to remain in a quantum state longer. That, in turn, makes them much more practical and effective. “A topological design is less impacted by changes in its environment,” Holmdahl said.

At the same time as Microsoft is working to build a quantum computer, it is also creating the software that could run on it. The goal is to have a system that can begin to efficiently solve complex problems from day one. “Similar to classical high-performance computing, we need not just hardware but also optimized software,” Troyer said.

To the team, that makes sense: The two systems can work together to solve certain problems, and the research from each can help the other side. “A quantum computer is much more than the qubits,” Reilly said. “It includes all of the classical hardware systems, interfaces and connections to the outside world.”

For more information on topological materials: http://idstch.com/home5/international-defence-security-and-technology/technology/materials/topological-materials-promising-ultra-low-power-faster-computers-microsofts-topological-quantum-computers/

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