Yale scientists make 2 giant steps in advancement of quantum computing

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Two major steps toward putting quantum computers into real practice — sending a photon signal on demand from a qubit onto wires and transmitting the signal to a second, distant qubit — have been brought about by a team of scientists at Yale. The accomplishments are reported in sequential issues of *Nature* on September 20 and September 27, on which it is highlighted as the cover along with complementary work from a group at the National Institute of Standards and Technologies.

Over the past several years, the research team of Professors Robert Schoelkopf in applied physics and Steven Girvin in physics has explored the use of solid-state devices resembling microchips as the basic building blocks in the design of a quantum computer. Now, for the first time, they report that superconducting qubits, or artificial atoms, have been able to communicate information not only to their nearest neighbor, but also to a distant qubit on the chip.

This research now moves quantum computing from "having information" to "communicating information." In the past information had only been transferred directly from qubit to qubit in a superconducting system. Schoelkopf and Girvin's team has engineered a superconducting communication 'bus' to store and transfer information between distant quantum bits, or qubits, on a chip. This work, according to Schoelkopf, is the first step to making the fundamentals of quantum computing useful.

The first breakthrough reported is the ability to produce on demand —

and control — single, discrete microwave photons as the carriers of encoded quantum information. While microwave energy is used in cell phones and ovens, their sources do not produce just one photon. This new system creates a certainty of producing individual photons.

“It is not very difficult to generate signals with one photon on average, but, it is quite difficult to generate exactly one photon each time. To encode quantum information on photons, you want there to be exactly one,” according to postdoctoral associates Andrew Houck and David Schuster who are lead co-authors on the first paper.

“We are reporting the first such source for producing discrete microwave photons, and the first source to generate and guide photons entirely within an electrical circuit,” said Schoelkopf.

In order to successfully perform these experiments, the researchers had to control electrical signals corresponding to one single photon. In comparison, a cell phone emits about 1023 (100,000,000,000,000,000,000,000) photons per second. Further, the extremely low energy of microwave photons mandates the use of highly sensitive detectors and experiment temperatures just above absolute zero.

“In this work we demonstrate only the first half of quantum communication on a chip — quantum information efficiently transferred from a stationary quantum bit to a photon or ‘flying qubit,’” says Schoelkopf. “However, for on-chip quantum communication to become a reality, we need to be able to transfer information from the photon back to a qubit.”

This is exactly what the researchers go on to report in the second breakthrough. Postdoctoral associate Johannes Majer and graduate student Jerry Chow, lead co-authors of the second paper, added a second qubit and used the photon to transfer a quantum state from one qubit to another. This was possible because the microwave photon could be guided on wires — similarly to the way fiber optics can guide visible light — and carried directly to the target qubit. “A novel feature of this experiment is that the photon used is only virtual,” said Majer and Chow, “winking into existence for only the briefest instant before disappearing.”

To allow the crucial communication between the many elements of a conventional computer, engineers wire them all together to form a data “bus,” which is a key element of any computing scheme. Together the new Yale research constitutes the first demonstration of a “quantum bus” for a solid-state electronic system. This approach can in principle be extended to multiple qubits, and to connecting the parts of a future, more complex quantum computer.

However, Schoelkopf likened the current stage of development of quantum computing to conventional computing in the 1950’s, when individual transistors were first being built. Standard computer microprocessors are now made up of a billion transistors, but first it took decades for physicists and engineers to develop integrated circuits with transistors that could be mass produced.

Source: Yale University

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