U-M develops scalable and mass-producible quantum computer chip

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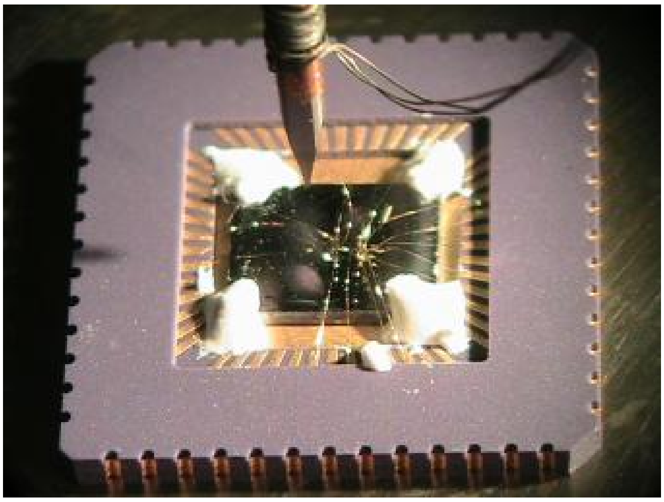

Researchers at the University of Michigan have produced what is believed to be the first scalable quantum computer chip, which could mean big gains in the worldwide race to develop a quantum computer.

Image: Semiconductor quantum computer chip being wired up.

Using the same semiconductor fabrication technology that is used in everyday computer chips, researchers were able to trap a single atom within an integrated semiconductor chip and control it using electrical signals, said Christopher Monroe, U-M physics professor and the principal investigator and co-author of the paper, "Ion Trap in a Semiconductor Chip." The paper appeared in the Dec. 11 issue of *Nature Physics*.

Quantum computers are promising because they can solve certain problems much faster than any possible conventional computer, owing to the bizarre features of quantum mechanics. For instance, quantum computers can process multiple inputs at the same time in the same device, and quantum circuitry can be wired via the quantum feature of entanglement, dubbed by Einstein as "spooky action-at-a-distance."

One of the most favored candidate quantum computer architectures is the use of individual atoms to store quantum bits (qubits) of information, where each qubit can hold the number 1 or 0, or even both 1 and 0 simultaneously, Monroe said. Electrically charged atoms (ions) for such quantum computers are stored in what are known as ion traps. Trapping is necessary in order to isolate the qubits from the rest of the world, which is absolutely essential for the system to behave quantum mechanically. It is well known how to program a quantum computer composed of any number of trapped ions; the problem is to get the ions trapped in the first place.

Current ion traps can only hold a few atoms or qubits, and are not easily scaled. Rather, these ion traps are assembled laboriously by hand. Therefore, one of the obstacles to perfecting the quantum computer is making a scalable integrated quantum computer chip that can store thousands or more atomic ions. For this reason, efforts in the area of quantum computing are now focused on making ion traps on a chip that are scalable and mass producible, and can host larger numbers of qubits.

"The semiconductor chip we demonstrated holds an individual atom in free space inside the chip—we levitate the atom in the chip by applying certain electrical signals to the tiny nearby electrodes," Monroe said. "We directly view this single atom with specially-tuned lasers and a sensitive camera. This type of ion trap has never been demonstrated at such a small level and in an integrated chip structure."

The chip produced at U-M is about as big as a postage stamp. It is etched with electrodes using a process called lithography, which eliminates the need for manual assembly. Each electrode is connected to a separate voltage supply, and these various electrical voltages serve to control the ion by moving it in different ways as it hovers in a space carved out of the chip.

Using existing microfabrication technology, the quantum chip developed at U-M could be scaled up to include hundreds of thousands of electrodes, Monroe said.

"There is a worldwide race to build these (chips) right now, as such an integrated chip structure shows a way to scale the quantum computer to bigger systems—just like the microfabrication of conventional chips have given us the impressive gains in conventional computing speed and power," Monroe said.

The next step is to build the chip bigger with many more electrodes, so that it can store more ions. "There is still a great deal of work to be done in order to learn how to control lots of ions in one of these chips. It won't be nearly as easy as it was with conventional computer chips, but at least we know what to do in principle," Monroe said.

Doctoral student Daniel Stick, in Monroe's group in the U-M Physics Department and FOCUS Center (Frontiers in Optical, Coherent, and Ultrafast Science), led this work in collaboration with the Laboratory for Physical Sciences at the University of Maryland.

Source: University of Michigan