Memoirs of a qubit: Hybrid memory solves key problem for quantum computing

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The silicon sample is shown in the resonator used in the experiment. The team created a system that used both the electron and nucleus of a phosphorous atom embedded in a silicon crystal. Both the electron and nucleus behaved as tiny quantum magnets capable of storing quantum information. This allows information to stay intact for over a second, an important threshold in the development of quantum computing. Courtesy of Stephen A. Lyon, Princeton University

An international team of scientists has performed the ultimate miniaturisation of computer memory: storing information inside the nucleus of an atom. This breakthrough is a key step in bringing to life a quantum computer - a device based on the fundamental theory of quantum mechanics which could crack problems unsolvable by current technology.

In the quantum world, objects such as atoms are allowed to exist in multiple states simultane-ously -- that is, they could literally be in two places at once or possess a number of other seemingly mutually exclusive properties. Quantum computing is seen as the holy grail of computing because each individual piece of information, or 'bit', can have more than one value at once, as opposed to current technology which is limited to either 1s or 0s. This yields unprecedented processing power and thus dramatically widens the scope of what computers can do.

The problem: How do you isolate a quantum bit from a noisy environment to protect the deli-cate quantum information, while at the same time allowing it to interact with the outside world so that it can be manipulated and measured?

The team, with scientists and engineers from Oxford and Princeton universities and Lawrence Berkeley National Laboratory, reported a solution to this problem in the Oct. 23 issue of the journal *Nature*.

The team's plan was to devise a hybrid system using both the electron and nucleus of an atom of phosphorous embedded in a silicon crystal. Each behaves as a tiny quantum magnet capa-ble of storing quantum information, but inside the crystal the electron is more than a million times bigger than the nucleus, with a magnetic field that is a thousand times stronger. This makes the electron well-suited for manipulation and measurement, but not so good for storing information, which can become rapidly corrupted. This is where the nucleus comes in: when the information in the electron is ready for storage, it is moved into the nucleus where it can survive for much longer times.

The experiments were made possible by the use of silicon enriched with the single 28Si iso-tope, painstakingly grown by the Berkeley team into large crystals while keeping the material ultra-pure and free from contaminants.

“The electron acts as a middle-man between the nucleus and the outside world. It gives us a way to have our cake and eat it - fast processing speeds from the electron, and long memory times from the nucleus,” said John Morton, a research fellow at St. John’s College, Oxford and lead author of the Letter to Nature.

Crucially, the information stored in the nucleus had a lifetime of about 1 and 3/4 seconds, ex-ceeding a recently calculated target for quantum computing in silicon beyond which known error correction techniques could then protect the data for an arbitrarily long period of time. Without this technique the longest researchers had been able to preserve quantum information in silicon was a few tens of milliseconds.

“Nobody really knew how long a nucleus might hold quantum information in this system. With the crystals from Lawrence Berkeley and very careful measurements we were delighted to see memory times exceeding the threshold,” said Steve Lyon, leader of the Princeton team.

Many different approaches to building a quantum computer are being studied, however one great advantage of the model used here is that it is based on silicon technology, which makes it more compatible with today’s computers.

Source: Princeton University

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