Lasers can lengthen quantum bit memory by 1,000 times

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Physicists have found a way to drastically prolong the shelf life of quantum bits, the 0s and 1s of quantum computers.

These precarious bits, formed in this case by arrays of semiconductor quantum dots containing a single extra electron, are easily perturbed by magnetic field fluctuations from the nuclei of the atoms creating the quantum dot. This perturbation causes the bits to essentially forget the piece of information they were tasked with storing.

A quantum dot is a semiconductor nanostructure that is one candidate for creating quantum bits.

The scientists, including the University of Michigan's Duncan Steel, used lasers to elicit a previously undiscovered natural feedback reaction that stabilizes the quantum dot's magnetic field, lengthening the stable existence of the quantum bit by several orders of magnitude, or more than 1,000 times.

The findings are published in the June 25 edition of *Nature*.

Because of their ability to represent multiple states simultaneously, quantum computers could theoretically factor numbers dramatically faster and with smaller computers than conventional computers. For this reason, they could vastly improve computer security.

"In our approach, the quantum bit for information storage is an electron spin confined to a single dot in a semiconductor like indium arsenide. Rather than representing a 0 or a 1 as a transistor does in a classical computer, a quantum bit can be a linear combination of 0 and 1. It's sort of like hitting two piano keys at the same time," said Steel, a professor in the Department of Physics and the Robert J. Hiller Professor of Electrical Engineering and Computer Science.

"One of the serious problems in quantum computing is that anything that disturbs the phase of one of these spins relative to the other causes a loss of coherence and destroys the information that was stored. It is as though one of the two notes on the piano is silenced, leaving only the other note."

Spin is an intrinsic property of the electron that isn't rotation, but is more like magnetic poles. Electrons are said to have spin up or down, which represent the 0s and 1s.

A major cause of information loss in a popular class of semiconductors called 3/5 materials is the interaction of the electron (the quantum bit) with the nuclei of the atoms in the quantum dot holding the electron. Trapping the electron in a particular spin, as is necessary in quantum computers, gives rise to a small magnetic field that couples with the magnetic field in the nuclei and breaks down the memory in a few billionths of a second.

By exciting the quantum dot with a laser, the scientists were able to block the interaction of these magnetic fields. The laser causes an electron in the quantum dot to jump to a higher energy level, leaving behind a charged hole in the electron cloud. This hole, or space vacated by an electron, also has a magnetic field due to the collective spin of the remaining electron cloud. It turns out that the hole acts directly with the nuclei and controls its magnetic field without any intervention from outside except the fixed excitation by the lasers to create the hole.

"This discovery was quite unexpected," Steel said. "Naturally occurring, nonlinear feedback in physical systems is rarely observed. We found a remarkable piece of physics in nature. We still have other major technical obstacles, but our work shows that one of the major hurdles to quantum computers that we thought might be a show-stopper isn't one," Steel said.

The paper is called "Optically-controlled locking of the nuclear field via coherent dark-state spectroscopy."

Source: University of Michigan (news : web)