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Harnessing polarised light to create quantum memory

The ability to store quantum information is a critical element in the quest to create quantum computers, devices that would vastly outstrip in power and speed any computer now in existence.

MUCH AS a journey of a thousand miles begins with a single step, the journey to a quantum computer begins with a single qubit - a single bit of quantum memory.

A first baby step in that journey was taken during an experiment in a University of Nebraska-Lincoln laboratory earlier this year when a team led by UNL physicist Herman Batelaan captured polarised light in a cell containing a vapour of atoms of the metal rubidium.

In the experiment, designed by Gao Hong, a post-doctoral student in Batelaan's lab, 20-microsecond pulses of polarised light were beamed into a tubular, 4-cm-long cell containing rubidium vapour, where the pulses were captured before being released intact.

Light normally moves through space at about 186,000 miles per second and a microsecond is one-millionth of a second, so a 20-microsecond light pulse normally would be about 3.72 miles long. But in Gao's experiment, that 3.72-mile-long light pulse was captured and stored in a tube about 1 1/2-inches in length.

That was a notable and interesting achievement, Batelaan said, but it only confirmed results published in 2001 by teams of scientists at Harvard University and the Harvard-Smithsonian Centre for Astrophysics, both in Cambridge, Mass.

Gao demonstrated that polarised light could be harnessed to create quantum memory.

The ability to store quantum information is a critical element in the quest to create quantum computers, devices that would vastly outstrip in power and speed any computer now in existence. In present-day computers, memory is stored as millions of zeros and ones on silicon chips. But the point of a quantum computer is to take advantage of how the laws of physics change at the atomic, or quantum, level, where it is possible to exist in more than one state simultaneously.

Something other than static ones and zeros on silicon chips, then, will be necessary for memory storage.

"If you have light going a certain way, you have an electric field that oscillates," Batelaan said. It can oscillate horizontally or it can oscillate vertically. Those are the zeroes and ones of your qubit in this case.

"But the problem is, suppose I want to make a quantum computer out of light. I need to do something with the light, but it goes by so quickly that I can't do anything with it.

So it would be nice to take that light and dump it into something so that we can actually do something with it."

Batelaan, Gao and their research team `dumped' the light into the rubidium tube, and found they were indeed able to do something with it. They created a quantum memory.

"The scientists at Harvard looked at one polarisation only, and what Gao is capable of doing is not only two polarizations, but all combinations," Batelaan said. "The fidelity for all polarisations is better than 95 per cent, so it is darn good. It shows that the polarisation state is well-maintained during storage in the rubidium cell. He clinched this issue that you can use polarised light as a qubit, as a one-qubit quantum memory."

A standard, run-of-the-mill desktop computer typically has more than 100 million bits of memory, however, and Batelaan readily acknowledges that there is a long way to go in the quest for a functional quantum computer.

"How many bits do you have in a typical computer memory? A boatload. How many do we have on our table? One," he said. But the difference between zero and one is often enormous and the obvious thing that we're discussing is how do we make more.

"It's anybody's guess what the future components of the quantum computers are going to be. But if you ask my guess, light is definitely going to play a major role, and some medium that can store the information, some material such as the rubidium that can talk to the light, is going to play a role. The process of how light talks to matter, that is what we are studying."