Researchers Demonstrate Quantum Teleportation and Memory in Tandem

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In research that may be a key step toward real-life quantum communication—the transmission of information using atoms, photons, or other quantum objects—researchers created an experiment in which a quantum bit of information is transported across a distance of seven meters and briefly stored in memory. This is the first time that both quantum memory and teleportation, as the information transfer is known, have been demonstrated in a single experiment.

The experiment was performed by scientists from the University of Heidelberg in Germany, the University of Science and Technology of China, and the Atomic Institute of the Austrian Universities in Austria. The work was led by Prof. Jian-Wei Pan, a physicist at the University of Heidelberg.

A quantum bit, or qubit, is the most basic unit of quantum information. It takes the form of a particular configuration, or "state," of an atom or photon. Unlike a traditional computer bit, the most basic piece of information a computer can store, qubits represent the superposition of "0" and "1," rather than *either* a 0 or 1. Additonally, a qubit cannot be copied in the traditional sense. It can only be transferred, without leaving any trace of the original.

Quantum teleportation is the way to transfer an unknown quantum state to a distant location without getting any information about the state in the course of this transfer. When a qubit is teleported across a distance, the process is remarkable in that the sending and receiving qubits are not physically connected in any way, and do not “know” of each other's existence. But through a quantum phenomenon called entanglement, one qubit is nonetheless able to assume the quantum state of another without physically interacting with it.

In the present research, described in the January 20 online edition of *Nature Physics*, an unknown quantum state of a photonic qubit is transferred into quantum memory via teleportation and is stored by two clusters of rubidium atoms. Each cluster contains approximately one million atoms, collected by a magneto-optical trap. The teleported photonic qubit can be stored in memory and read out up to eight microseconds (millionths of a second) before the state is lost.

“Such an interface to map the quantum states of photons onto the quantum states of matter, and to retrieve them without destroying the quantum character of the stored information, is an essential part of future quantum technologies,” said Pan to *PhysOrg.com*. “It represents an important step towards efficient and scalable connection of quantum networks.”

The quantum states carried by the photonic qubits are encoded in the photons' polarization, or the alignment of the photons' emitted electric fields. Each rubidium cluster encodes the information as a collective spin state over all of the electrons in the cluster. Like other unchangeable properties like mass and charge, spin, or angular momentum, is an intrinsic characteristic of an electron.

First, the research group entangled the polarization state of the photons and the spin state of the atom clusters. This entanglement is then exploited to teleport the unknown state of a single photonic qubit onto an atomic qubit seven meters away. This is done by taking a simultaneous measurement of the entangled photons and the photon to be teleported. Taking that measurement entangles the two photons and projects the second photon's state onto the atom clusters.

This setup does have some serious problems. The quantum memory duration is very short and the probability that the photon will be teleported is low. Therefore, the researchers say that “significant improvements” need to be made before the scheme could be used in practical applications.

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