Scientists Extend the Lifetime of Quantum Memory

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(PhysOrg.com) -- Storing and sending information using quantum phenomena is one of the hottest areas of research today; scientists across the globe are investigating how to make quantum communication possible for real-life applications. In a key step, a group of researchers was recently able to greatly improve the lifetime of a form of quantum memory.

In this case the research group achieved a quantum memory lifetime of 6 ms, more than 100 times as long as the next-best reported time. The scientists—from the Georgia Institute of Technology, the University of Maryland, and Università degli Studi dell'Insubria (Unviersity of Insubria), in Italy—describe their work in the December 7 online edition of *Nature Physics*.

"Though several technical hurdles still remain, this advance represents a significant step toward the realization of quantum networks and the distribution of entangled states over long distances," said corresponding author Stewart Jenkins to *PhysOrg.com*. Jenkins is affiliated with both Georgia Tech and the University of Insubria.

Quantum memory schemes are extremely sensitive to the surrounding environment, limiting how long they can store data. To transmit quantum information over a long distance, the storage times must be longer than scientists have been able to achieve thus far. Transmitting quantum information across 1,000 kilometers, for example, takes a minimum of 5 milliseconds (ms), meaning that a quantum-memory scheme must be viable for at least that long.

This group's work takes advantage of rubidium's "clock transition," the movement of electrons between two specific energy levels. This electron jump is what makes rubidium atoms appropriate for use in atomic clocks, in which the standard for keeping time is based on the precise (and unchanging) frequency of microwaves emitted when the electrons undergo the transition.

The transition is the medium by which the atoms store quantum information. The process involves three key atomic energy levels, denoted *a*, *b*, and *c*, where a is the lowest and c is the highest. The energy difference between *a* and *b* is very small; they are "hyperfine" levels of the ground state, the lowest state of an atom.

Jenkins and his colleagues trapped between 100,000 and one million super-chilled rubidium atoms within a lattice of laser beams, which separated and immobilized the atoms into a grid-like pattern. They then "set" the atoms to the proper excitation state using a "write" laser, imparting the atom's electrons with enough energy to move from b up to c. The transition represents a value of one bit, the most basic unit of information, typically denoted as a "0" or "1." (In conventional memory schemes, bits are often defined by capacitors, with a charged capacitor representing a "1" and an uncharged capacitor representing a "0.")

The electrons quickly decayed from the c level, but jumped down to *a* rather than back to *b*. This is due to energy loss from the light they emitted during the jump, know as Raman radiation.

Finally a "read" laser was applied to the atom array, exciting the *a*-to-*c* transition. The electrons decayed from *c* to *b*, emitting a second, weaker round of Raman emission, known as the "idler" field. The idler field is detected and interpreted, allowing the researchers to "read off" the information that had been briefly stored.

This approach differs from previous rubidium quantum-memory schemes. The longest memory time prior to this work was achieved using a free-moving, magnetically sensitive rubidium-atom ensemble; it had a lifetime of 32 microseconds. But the atoms were able to fall freely, which, in conjunction with small magnetic fields, resulted in a limited memory time.

In this case, the atoms' motion is greatly suppressed and the clock transition is not sensitive to magnetism. These features greatly improve the memory time.

Quantum communication is based on the phenomenon of entanglement, the mysterious way in which two quantum entities, such as photons (light particles), can "know" each other's quantum state despite never having been in contact. Parties in remote locations share and store the entangled state, thus transmitting a quantum bit across a distance.

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