Nature Physics: Quantum Teleportation between Flying (Photonic) and Stationary (Atomic) Qubits

In its upcoming issue the science journal Nature Physics will publish the article:
Memory-built-in quantum teleportation with photonic and atomic qubits.
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Quantum states (quantum bits) are very fragile. Different physics systems have complementary advantage in sending, manipulating or storing quantum states. Photons for example are ideal choice for communicating a quantum state: they are fast and very robust, but they are difficult to store. Atomic states are ideal long lived quantum states which can be used to store quantum bits. Their inherent precision and long coherence times are the basis of atomic clocks. It has been a challenge to connect the two by a quantum interface.

In the recent article published on 20th January in the journal Nature Physics (Advanced-Online-Publication) scientists from the University Heidelberg, University of Science and Technology of China, and the TU-Vienna experimentally demonstrated how an unknown state of a photonic qubit can be transferred into a quantum memory by quantum teleportation, stored in the atomic states of the quantum memory for up to 8 micro-second and then read out and transferred on to photonic state.

Such an interface to map quantum states of photons to these quantum states of matter and to retrieve them without destroying the quantum character of the stored information is an essential part of a future quantum technology.

How to accomplish this task?

In the classical world it is possible to copy and send information, for example in a fax machine. However, in quantum world this is not possible. Quantum information can not be copied, it can only be transferred, without leaving any trace remaining on the original. How can we transfer a state of a quantum system from one place to another?

In quantum teleportation an unknown quantum state is transferred to a distant location without getting any information about the state in the course of this transformation. It is one of the most intriguing examples of how quantum entanglement can assist in realizing practical tasks and is involved in numerous quantum communication and quantum computation schemes.

Both quantum teleportation and quantum memory have been achieved separately in many proof-of-principle experiments, but the demonstration of memory-built-in teleportation of photonic qubits remained an experimental challenge.

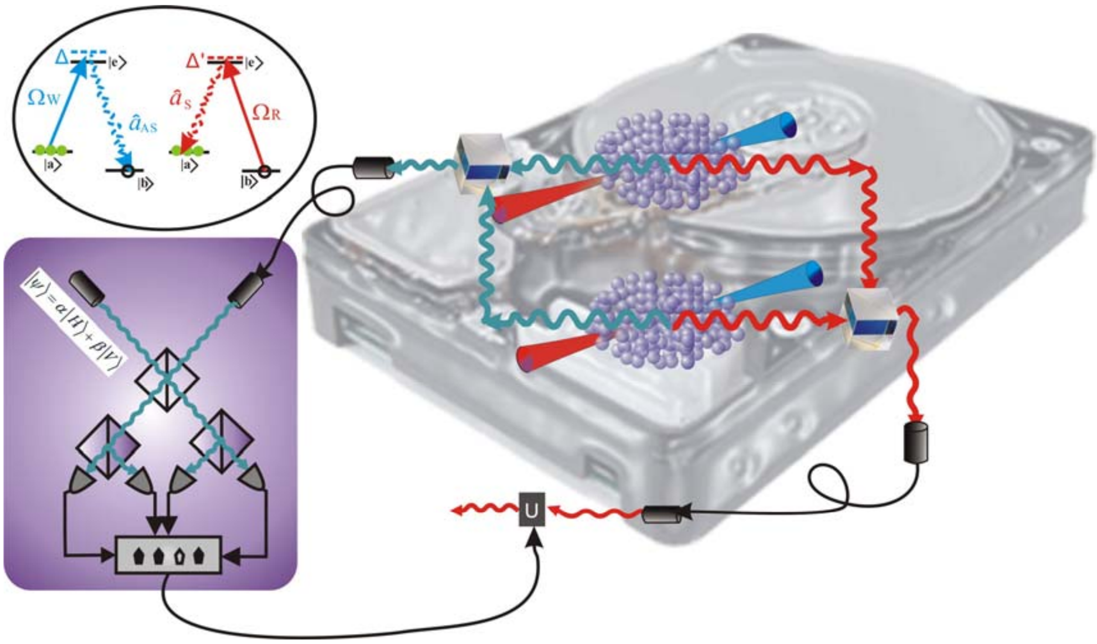

Figure: Experimental setup.

In the present experiment the scientists used photonic qubits with the quantum information encoded in the polarization as the information carriers and the collective atomic spin excitation in an ultra cold ensemble of about a million Rb atoms as the quantum memory. At first an entanglement between the photonic polarization state and the state of the quantum memory is created. This atom-photon entanglement is then the resource, which is exploited to teleport an unknown polarization state of a single photon onto a remote atomic qubit via a Bell-state measurement between the photon to be teleported and the photon that is originally entangled with the atomic qubit. The teleported state can be then stored in the collective state of atomic ensembles and successfully retrieved for a delay of up to 8 micro-seconds.

The successful teleportation is verified by the experimentally determined fidelity of the teleported state, which is greater than the classical limit two thirds.

Besides being of fundamental interest, the present experiment of memory-built-in teleportation protocol with the direct inclusion of a readable quantum memory represents an important step towards efficient and scalable connection of quantum networks.