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Press Release

Quantum memory for light

Danish-German research team demonstrates a memory of quantum state of a light pulse in an atomic ensemble.

In the macroscopic classical world, it is possible to copy information from one device into another. We do this everyday, when, for example, we copy files in a computer or we tape a conversation. In the microscopic world, however, it is not possible to copy the quantum information from one system into another one. It can only be transferred, without leaving any trace on the original one. The manipulation and transfer of quantum information is, in fact, a very active field of research in physics and informatics, since it is the basis of all the protocols and algorithms in the fields of quantum communication and computation, which may revolutionize the world of information. In the work published in "*Nature* 432, 482, 2004", scientist from the Max-Planck Institute for Quantum Optics in Garching and the Niels Bohr Institute in Copenhagen have proposed a scheme to transfer the quantum state of a pulse of light onto a set of atoms and have demonstrated it experimentally.

In the experiment, a pulse of light is prepared in a certain quantum state whose properties (polarization) are randomly chosen. Then, the light is sent through a set of atoms which are contained in a small transparent box (an atomic cell) at room temperature. In the cell, the light and atoms interact with each other, giving rise to an “entangled” state in which the two systems remain correlated. After abandoning the atomic sample, the pulse of light is detected. Due to the fact that the light and atoms are entangled, the process of measurement on the light affects the quantum state of the atoms in such a way that they acquire the original properties of the light. Thus, in this way, the state of polarization of the photons is transferred into the polarization state of the atoms. This “action at a distance”, in which by performing a measurement on a system it affects the state of another system which is at a different location is one of the most intriguing manifestations of Quantum Mechanics, and is in fact the basis of applications like quantum cryptography or phenomena like teleportation.

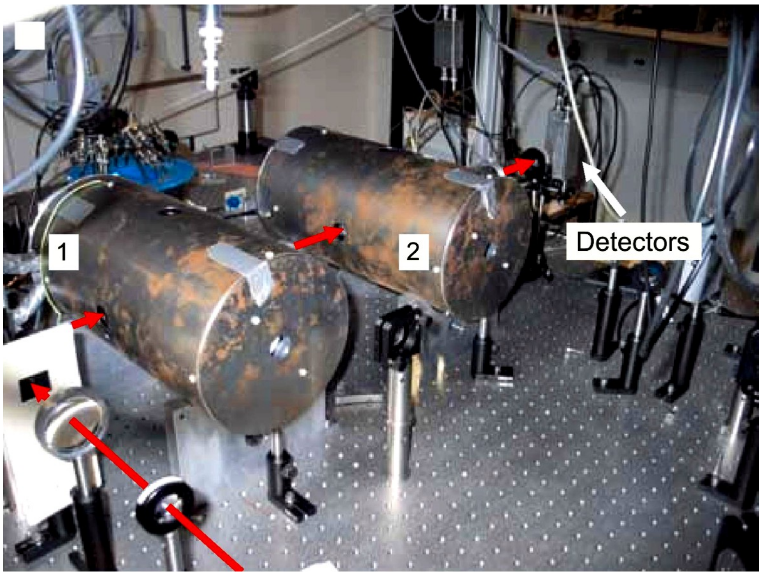

Figure:
Experimental set-up: Atomic memory unit consisting of two caesium cells inside magnetic shields 1 and 2. The path of the recorded and read-out light pulses is shown with arrows.

Image: Max-Planck-Institute of Quantum Optics / Niels Bohr Institute Copenhagen

In order to check that indeed, the transfer of polarization has taken place, one measures at the end the polarization of the atoms and compares it with the original one of the light. In the experiment, these two polarizations coincided up to a 70%. The main reason for the imperfections where the due to spontaneous emission, a process in which the atoms absorb the photons but then emit them in a different direction such that they do not go towards the photodetector.

A question that the authors of the paper had to carefully analyze was to what extent 70% percent of coincidence is enough to claim that the process was successful. Or, in other words, could they obtain the same result by measuring the state of polarization of the photons and then prepared the state of the atoms accordingly? The answer is no. Due to the basic properties of quantum mechanics, the state of polarization of a laser pulse cannot be fully detected. Due to the Heisenberg uncertainty principle, it is impossible to measure the full polarization exactly. In fact, as some of the authors together with K. Hammerer and M. Wolf (from the Max-Planck Institute for Quantum Optics) have recently shown, the best one can do using this latter method would be 50%. This implies that the experiment indeed has successfully demonstrated the transfer beyond what one could do without creating the entangled state.

The present experiment paves the way to new experiments in which the information contained in light can be mapped onto atomic ensembles and then back into the light again. In this way, one could not only store the state of light in an atomic ensemble, but also retrieve it. This process will be necessary if we want to build quantum repeaters, that is, devices which will allow to extend quantum communication much beyond the distances (of the order of 100 km) which are achieved nowadays.

Original work:

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Experimental demonstration of quantum memory for light
Nature **432,** 482 (2004)

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