Press release:

New progress in quantum communication: Physicists realized a robust quantum repeater node

Scientists from the University of Heidelberg, the University of Science and Technology of China, and the TU-Wien have taken a new step towards long-distance quantum communication. They realized a robust quantum repeater node that has the potential to be utilized as building blocks in the future quantum communication network.

In any long distance communication channel, one has to overcome the attenuation and loss by amplifying the transmitted signal. This is accomplished in repeater stations which regenerate (amplify) the transmitted signal. In transmitting quantum information the no cloning theorem of quantum physics, same fundamental principle which makes quantum communication unconditional secure, prevents the simple amplification of the quantum signal, and therefore the straight forward implementation of the quantum analog of a repeater station.

In the August 28 issue of the scientific journal Nature, Jian-Wei Pan and his colleagues report now the realization of such a robust quantum repeater node, by demonstrating for the first time entanglement swapping with storage and retrieval of light. Entanglement, the essential resource for quantum information processing, has been generated between two remote atomic ensembles connected with 300-m fibre, which is verified by converting the atomic excitation into photons after a definite storage time.

In recent years, secure transfer of information has attracted much attention. Quantum communication, the way of transferring information encoded in quantum states (quantum bits, or qbits as they are often called) offers efficient and **unconditionally** secure ways for the exchange of information in a network. The absolute security is guaranteed by the fundamental laws of quantum physics. Presently, the bottleneck in using quantum states to transfer information is the limited communication distance due to inevitable losses in the transmission channel. This implies that the resources required grow exponentially with the channel length.

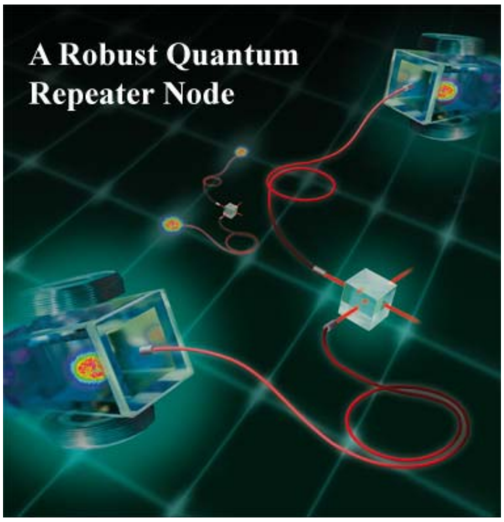
To break this bottleneck, in 1998, Briegel, Dür, Cirac and Zoller (BDCZ) proposed to build quantum repeaters. The basic idea is to divide the communication channel into many shorter segments; entanglement is established first in each segment with a proper fidelity; then the entanglement is extended to larger distance by connecting the adjacent segments sequentially by entanglement swapping. Embedded entanglement purification has to be exploited when the fidelity of the entanglement is degraded to a predefined threshold. Even though a probabilistic protocol, the resources required grow only polynomially with communication distance if the entanglement created at intermediate distances can be stored in a quantum memory.

The challenge was how to combine the original BDCZ strategy with a quantum memory. This has been successfully demonstrated in the present work and led to the realization of an essential building block of a BDCZ type quantum repeater.

In the experiment starts with two ensembles of about one million (10^6) atoms each, cooled to 100 micro kelvin in two magneto-optic traps. In a first step a quantum state in each ensemble is entangled with the quantum state of a single emitted photon. The stored quantum states in the atomic ensembles are then projected into an entangled state by performing a joint Bell-state measurement on the two single photons after they have passed through a 300-m fibre-based communication channel. The created entanglement is now stored in the atomic ensembles and can later be verified, or used as a resource, by converting the stored quantum states back into photons.

The method employed in this experiment, entanglement swapping by a joint Bell-state measurement is intrinsically insensitive to path length fluctuations in the communication channel or changes in the phase of the transmitted photon and establishes the essential element needed to realize quantum repeaters with stationary atomic qubits as quantum memories and flying photonic qubits as quantum messengers. While these elements can be in principle extended straightforward to a quantum network, for a robust larger scale implementation the quality of the quantum memory and the fidelity of the atom-photon entanglement still need to be improved significantly.

In a closely related experiment (published last week in the journal Physical Review Letters) the same Heidelberg/Vienna/USTC collaboration was able to demonstrate, though without the inclusion if a quantum memory, that entanglement swapping and creation works even when extended to swapping through an intermediate step, 2 communication segments.



[Figure: In a quantum network, two neighboring nodes each containing an atomic ensemble (loaded by magneto-optical traps in vacuum glass cells, serving as quantum memories) and entangled with a single photon they emit, are projected into an entangled state by performing a joint Bell-state measurement on the two single photons after they have passed through a 300-m fibre-based communication channel. The entangled state stored in the atomic ensembles can be read out for further connections. The red curve, whose color from bright to dark, represents the degree of photon loss. The glass cube is a polarizing beam splitter for the joint Bell-state measurement. (Artwork by Julia Gless)]

Original work:

Experimental demonstration of a BDCZ quantum repeater node

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Nature 454, 1098 DOI: 10.1038/nature07241.

Multistage entanglement swapping

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Phys. Rev. Lett. 101, 080403 (2008).