Multiplexed quantum teleportation from a telecom qubit to a matter qubit through 1 km of optical fibre

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Distribution of quantum information over long distances is a basic need in the field of quantum communications. Quantum teleportation is an important capability that uses quantum entanglement as a resource to transmit arbitrary quantum bits (qubits) between distant parties [1]. A scalable implementation of quantum teleportation should feature compatibility with the telecom infrastructure and a multimode capability that allows for the decoupling of the repetition rate of the set-up from the distance between parties [2]. Moreover, the information should be transferred to a matter qubit with a storage time longer than the communication time such that the receiver can process the quantum states after they have been teleported.
In order to address all of these needs, we use a cavity-enhanced spontaneous parametric down-conversion source to create entangled photon pairs. The idler photon is created in the telecom band and the signal photon is compatible with storage in a solid-state quantum memory based on a praseodymium-doped crystal [3].
We used a source of time bin qubits to encode arbitrary states to be teleported.
We tested the system under a long distance scenario by separating sender and receiver with 1 km of optical fibre. We checked that the fidelity was the same as without the added distance (Fig. 1a). Thanks to the storage in the quantum memory, we could implement a unitary transformation on the teleported qubit conditioned on the result of the remote Bell-state measurement. Finally, we demonstrated that the teleportation repetition rate did not affect the fidelity of the teleported state (Fig. 1b, 1c).
We believe that these results represent a functional and scalable realization of long distance quantum teleportation and will inspire future implementations of long distance quantum teleportation.

References

[1] Bennett, C.H. et al. Phys. Rev. Lett. 70, 1895 (1993).
[2] Simon, C. et al. Phys. Rev. Lett. 98, 190503 (2007).
[3] Rakonjac, J. V. et al. Phys. Rev. Lett. 127, 210502 (2021)

Figures

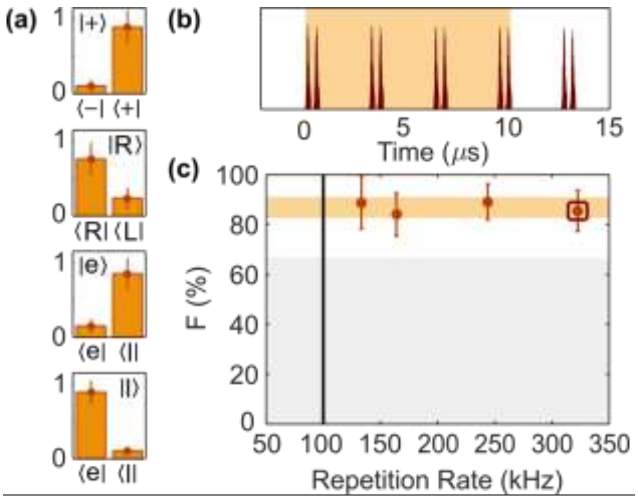

Figure 1: (a) Long distance quantum teleportation with an average fidelity of 86(4) %. Normalized coincidences for different input qubits after a qubit analyser with parallel and orthogonal settings. (b) Example of input qubit. Orange area represents the storage time in the quantum memory for that specific measurement. (c) Fidelity as a function of teleportation repetition rate. The black vertical line represents the maximum repetition rate for a single mode quantum memory after 1 km of distance in fibre. The grey area represents the classical limit of 66.7%. The orange area shows one standard deviation with respect to the average between all the measured fidelities.