Distribution of Quantum Correlations Across a Metropolitan Deployed Network Using a Solid-State Quantum Memory Array

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Long-distance quantum communication relies on quantum repeaters to overcome photon loss [1]. Quantum repeaters distribute entanglement among distant nodes via entanglement swapping. However, the communication time between the nodes limits the entanglement rate, as successive entanglement generation attempts must wait for the propagation of photons through the channel and for the return of a classical signal heralding the success or failure of each trial [2]. Multi-mode quantum memories address this limitation as entanglement attempts are generated in different degrees of freedom. The Atomic Frequency Comb (AFC) protocol provides intrinsic temporal multimodality [3], which has recently been combined with spatial multiplexing to reach solid-state spin-wave quantum memories with a large number of spatio-temporal modes [4, 5].

In this work, we demonstrate quantum correlations between a multiplexed on-demand quantum memory and a telecom photon detected at a distance. Our quantum network testbed comprises a solid-state quantum memory array (Pr:YSO) with ten individual controllable and temporally multiplexed memory cells and a cavity-enhanced SPDC source, both located in the Institute of Photonic Sciences (ICFO) and connected to a laboratory in the Collserola Tower by a 39.1-km-long deployed fibre. The two-way communication time between the two laboratories is 397 μs. Quantum correlations are generated by the photon-pair source, which emits correlated pairs of signal photons at 606 nm and idler photons at 1552 nm. Signal photons are stored locally on demand in the quantum memory array in a first-in-first-out fashion using the full AFC scheme while the idler photons are sent in the fiber network and detected in Collserola. We measure a cross-correlation of $g_{s,i}^{(2)} = 4.8(3)$ averaged over the ten memory cells which represents the first demonstration of single-photon storage in a multiplexed solid-state quantum memory array. We also detect up to 14 correlated idler events per second for a total of 60 spatio-temporal modes, which represents a 60-fold increase with respect to single-mode operation. A total of 15% of the communication time is filled with useful heralding events, a ten-fold increase from a single AFC memory due to the number of memory cells. These measurements constitute the first practical enhancement on the quantum correlation distribution rate at a distance via multiplexing using on-demand solid-state quantum memories. Our results highlight the prospects of this system for the distribution of long-distance entanglement at high rates.

References

[1] S. Wehner, et al , Science **362**, 9288 (2018).
[2] C. Simon, et al, Phys. Rev. Lett., **98**, 190503 (2007).
[3] M. Businger, et al. Nat. Commun., **13**, 6438 (2022).
[4] M. Teller, et al npj Quantum Information, **11**, 92 (2025)
[5] M. Teller, et al. Phys. Rev. X, **15**, 031053 (2025).