Quantum Repeater Link Demonstrations with Photon Pair Sources and Rare-Earth Based Multimode Memories

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The ability to distribute heralded entanglement between distant matter nodes is a primitive for the implementation of large-scale quantum networks [1-2]. We present our recent progress toward the experimental demonstration of quantum repeater links based on photon-pair sources and multimode solid-state quantum memories using rare-earth-doped crystals. Our approach focuses on "single-click" entanglement generation protocols, where entanglement between remote multimode memories is heralded by the detection of a single photon after coherent mixing at a central station [3]. This approach offers improved rate scaling with photonic channel losses, at the cost of increased phase-stability requirements.

We combine narrowband parametric photon-pair sources (cSPDC) [4] and solid-state quantum memories (QM) based on rare-earth doped crystals [5] to demonstrate telecom-heralded entanglement between spatially separated spin-wave quantum memories with fully adjustable recall time and temporal multiplexing of 15 modes. We show the heralding of memory-memory entanglement at a rate of up to 510 counts/s, with an associated detection rate of 0.32 counts/s and measure positive concurrence by up to 6 standard deviations [6]. We then discuss extending the protocol to so-called "two-single-click" to map the entangled state onto a two-photon state more suitable for direct quantum information processing [3]. We show preliminary results and outline progress towards a full experimental demonstration. Our results outline a viable path toward scalable solid-state quantum repeater nodes and represent a key step toward long-distance quantum networks based on multiplexed light–matter interfaces.

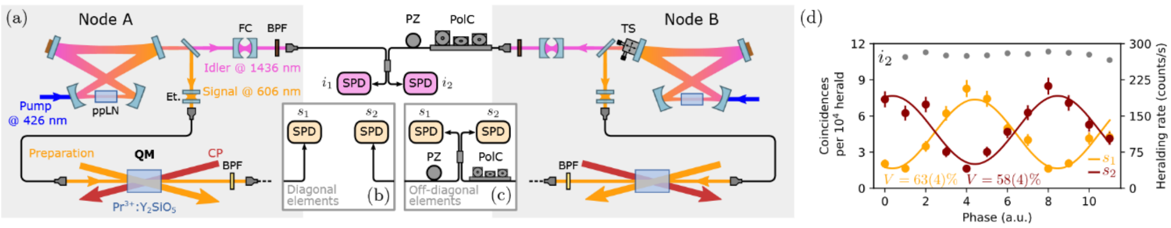

Fig. 1: *a) Experimental setup consisting of 2 cSPDC sources and 2 QMs. The detection of an idler photon after a 50/50 BS heralds an entangled state of a delocalized excitation shared across the two QMs. For density matrix reconstruction, single photons retrieved from the memory crystals are either (b) directly detected (diagonal elements measurement) or (c) interfered at a 50/50 BS (off-diagonal elements measurement). (d) Single photon interference of the signal modes at the memory output upon heralding from the central station.*

References

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