Scalable high-bandwidth quantum network platform with a room temperature quantum memory and a quantum dot single photon source.

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Quantum networks enable long distance entanglement distribution and establish a channel for quantum information transfer between various quantum nodes. An efficient quantum network comprises of a chain of quantum repeaters or quantum memories which preserve and distribute entanglement throughout a communication protocol. Hence, for a reliable network, quantum memories need to show promise in terms of scalability, broad bandwidth and low experimental complexity. Atomic vapor quantum memories satisfy these requirements [1] and recently have shown successful non-classical retrieval of broadband single photons [2], and also an implementation with microfabricated vapor cells [3].

As part of a collaboration '*Scalable High Bandwidth Quantum Network (sQnet)*', we aim to build a robust quantum network platform using Rb-like quantum dot single photon sources obtained in-house from the Warburton group at the University of Basel. These sources will then be interfaced with a GHz bandwidth quantum memory. First, the quantum memory will be implemented with warm-Rb vapor in a glass-blown vapor cell consisting of a channel with transverse diameter of 500 μm and 76 mm long, which is also anti-relaxation coated with octadecyltrichlorosilane (OTS). The memory operation can then be scaled to a microfabricated vapor cell developed at the CSEM, Neuchâtel. In a next step, we plan to implement an efficient on-chip frequency conversion of near-IR single photons to telecom wavelengths for lossless transmission over large distances. Using this hybrid network architecture, entanglement distribution with single photons in such a quantum memory can be demonstrated for the first time [4]. Furthermore, it lays out the foundation for performing complex networking tasks such as spectral and spatial multiplexing of single photons for efficient high bandwidth operation across multiple nodes. The entanglement distribution scheme is presented in the sketch in Figure 1.

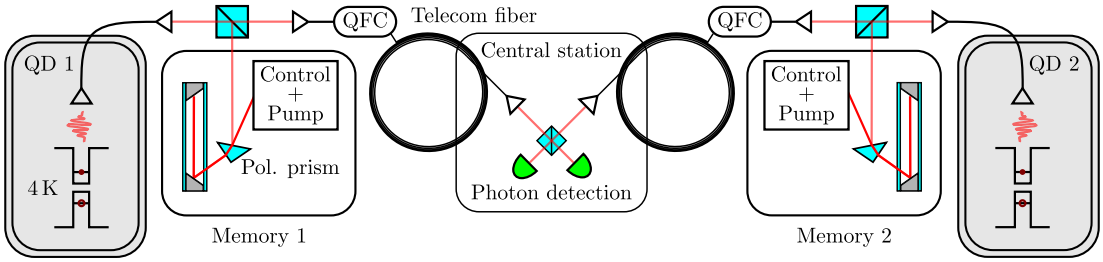

Figure 1. Remote entanglement distribution scheme using two GaAs quantum dot single photon sources interfaced with two room temperature quantum memories in warm-Rb vapor with transmission to the central station using telecom links carrying frequency converted single photons enabling long distance entanglement distribution.

[1] C. Simon, M. Afzelius, J. Appel, A. Boyer de la Giroday, S.J. Dewhurst, N. Gisin, C. Y. Hu, F. Jelezko, S. Kröll, J. H. Müller, J. Nunn, E. S. Polzik, J. G. Rarity, H. De Riedmatten, W. Rosenfeld, A. J. Shields, N. Sköld, R.M. Stevenson, R. Thew, I.A. Walmsley, M.C. Weber, H. Weinfurter, J. Wrachtrup, and R.J. Young, Quantum memories, Eur. Phys. J. D **58**, 1–22 (2010).

[2] G. Buser, R. Mottola, and P. Treutlein, Optical memory in a microfabricated rubidium vapor cell, Physical Review Letters **131**, 260801 (2023).

[3] R. Mottola, G. Buser, and P. Treutlein, Optical memory in a microfabricated rubidium vapor cell, PRL **131**, 260801 (2023).

[4] N. Sangouard, C. Simon, J. Minář, H. Zbinden, H. de Riedmatten, & N. Gisin, Long-distance entanglement distribution with single-photon sources, Physical Review A, **76**(5), 050301 (2007).