Atomic vapor quantum memory for on-demand semiconductor single photon sources

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Quantum memories can substantially increase the efficiency of long-distance communications by synchronizing entanglement swapping operations in quantum repeater nodes [1]. To build a quantum memory, Electromagnetically Induced Transparency (EIT) in atomic vapors can be exploited to coherently store light pulses even at room temperatures [2,3]. As a quantum source of light, semiconductor Quantum Dots (QD) offer bright on-demand single photons with high purity [4]. Interfacing QDs with atomic vapors has been shown by "slow light" [5] but a quantum memory for QDs is yet to be demonstrated.

In this project, we develop an EIT quantum memory hosted in warm cesium vapor. Storage of faint coherent light pulses on the single photon level were already successful and showed high storage efficiency. A measured bandwidth in the order of 200 MHz makes the memory compatible with the Fourier-limited emission of QDs embedded in micropillar cavities. An important next step in the project is now to interface the emission from a QD-micropillar with the quantum memory by fine-tuning the emission wavelength of the emitters to one of the hyperfine transitions in Cs, where the EIT memory takes place. If successful, this sets the base for the main goal of the project, i.e., a hybrid quantum memory based on atomic ensembles for an on-demand semiconductor single-photon source. In mid-term the quantum memory will become an important functional tool to synchronize, store and manipulate non-classical states of light.

[1] P. van Loock *et al.*, Adv. Quantum Technol. **3**, 1900141 (2020).
[2] O. Katz and O. Firstenberg, Nat. Commun. **9**, 2074 (2018).
[3] J. Wolters *et al.*, Phys. Rev. Lett. **119**, 060502 (2017).
[4] H. Wang *et al.*, Phys. Rev. Lett. **116**, 213601 (2016).
[5] T. Kroh *et al.*, Sci. Rep. **9**, 1 (2019).

Photonics for Quantum 2023 – 100 words summary

Quantum memories greatly increase the efficiency of quantum repeaters, enabling long-distance communications in quantum networks. Here we present a quantum memory based on atomic vapors capable of storing broadband single photons with high efficiency. These properties make the memory suitable for storing light from bright and highly pure on-demand single photon sources, semiconductor Quantum Dots. We also show the first attempts to interface our quantum memory with this type of single photon sources by fine-tuning the emission to the hyperfine transitions of our atomic vapor. This paves the way to a hybrid atomic vapor memory for quantum dots.

Photonics for Quantum 2023 – keywords

quantum memory, quantum dots, semiconductor, single photons, quantum networks, hybrid interfaces, storage, broadband, quantum repeater, atomic vapor, atomic memory.