Broadband quantum memory for photon synchronization at room temperature

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Future quantum photonic networks require coherent optical memories for synchronizing quantum sources and gates of probabilistic nature. We demonstrate a fast ladder memory (FLAME) mapping the optical field onto the superposition between electronic orbitals of rubidium vapor. Employing a ladder level-system of orbital transitions with nearly degenerate frequencies simultaneously enables high bandwidth, low noise, and long memory lifetime. We store and retrieve 1.7-ns-long pulses, containing 0.5 photons on average, and observe short-time *external* efficiency of 25%, memory lifetime $(\mathbf{1/e})$ of 86 ns, and below $\mathbf{10^{-4}}$ added noise photons. One immediate consequence is that coupling this memory to a probabilistic source would enhance the *on-demand* photon generation probability by a factor of 12, the highest number yet reported for a noise-free, room-temperature memory. This paves the way towards the controlled production of large quantum states of light from probabilistic photon sources. Yet another important extension of this work would be extending the ladder scheme to high lying Rydberg states for quantum non-linear optics experiments. To this end, we also introduce a tapered fiber into the atomic vapor, enabling simultaneously both tightly focused beams and high OD.

[1] R. Finkelstein, E. Poem, O. Michel, O. Lahad, and O. Firstenberg, ”Fast, noise-free memory for photon synchronization at room temperature”, Science Advances 4 (2018).