Optical Memory in a Microfabricated Rubidium Vapor Cell

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Optical interconnects that reversibly map quantum states between matter and light are fundamental for the realization of quantum networks. Their building blocks are single-photon sources and quantum memories. Ground-state atomic vapor memories are attractive due to the experimental simplicity that comes with room-temperature operation and have been proven to perform well in a multitude of figures of merit [1]. In particular, their noise performance has been shown to be compatible with preserving the non-classical photon-number statistics of the retrieved photons [2]. Furthermore, their acceptance bandwidth can be matched to high quality single-photon sources such as semiconductor quantum dots [3] or SPDC sources [4]. For realistic large-scale visions of quantum network architectures, a scalable and mass-producible platform is essential. Microfabrication techniques were already successfully used to implement compact quantum sensors, such as atomic clocks, magnetometers, and gyroscopes. However, so far, no quantum memory has been realized in a MEMS vapor cell. Recently, we demonstrated for the first time an optical memory in a microfabricated vapor cell compatible with wafer-scale fabrication techniques [5], representing a crucial step towards scalability.

This result was made possible by a novel quantum memory scheme. By applying a tesla-order static magnetic field, we are able to engineer a "clean" atom-light interaction by spectrally isolating an atomic lambda system in the hot ensemble. The magnetic field brings the atomic vapor into the hyperfine Paschen-Back regime: Zeeman degeneracies are lifted and the nuclear and total electronic spin are decoupled. This enables efficient, low-noise light storage in atomic ground states. In this proof-of-principle storage and retrieval experiment, we were able to store and retrieve weak coherent pulses attenuated to the single-photon level with a SNR = 7.9(8). So far, the signal-to-noise ratio has been limited by poor initial atomic polarization, caused by radiation trapping. For the next iteration of experiments, the geometry and filling of the cell have been optimized to increase the initial atomic state preparation. Furthermore, a customized permanent magnet was assembled to generate a static field with ppm-level homogeneity on the centimeter scale. With these improvements, new interfacing attempts of the memory with a single-photon source will be performed. An optical interconnect with miniaturized memories would pave the way to more complex room-temperature networking applications.

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