Microfabricated atomic memory in the hyperfine Paschen-Back regime

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Optical interconnects that reversibly map quantum states from light to matter constitute the backbone of quantum networks. Their building blocks are single-photon sources and quantum memories. Ground-state atomic vapor memories have been proven to perform well in a multitude of figures of merit [1]. With all components at room-temperature or above, no cryogenics nor ultra-high vacuum components are required, making vapor cells a promising platform due to their ease of operation. Furthermore, their acceptance bandwidth can be matched with high-quality single-photon sources as semiconductor quantum dots [2] or SPDC sources [3]. Realistic large-scale visions of quantum networks require a scalable and mass-producible platform. Microfabrication techniques are very promising and were successfully used to implement compact quantum sensors, as atomic clocks, magnetometers, and gyroscopes. However, realizing a quantum memory in a MEMS vapor cell remained an open challenge. Recently, we implemented for the first time an optical memory in a microfabricated vapor cell compatible with wafer-scale fabrication techniques [4] - a crucial step towards scalability.

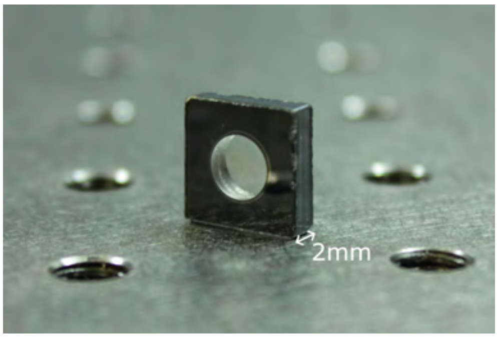

Figure 1. Microfabricated atomic vapor cell used for the implementation of the optical memory. The micro-cell is compatible with wafer-scale fabrication – a single wafer could hold hundreds of independent memories. These fabrication techniques pave the road for scalability and spatial-multiplexing.

This result was made possible by a novel quantum memory scheme, where we engineer “clean” atom-light interaction by spectrally isolating an atomic lambda system in the hot ensemble with the help of a tesla-order static magnetic field. The magnetic field brings the atomic vapor into the hyperfine Paschen-Back regime, lifting Zeeman degeneracies and decoupling nuclear and total electronic spin. This enables efficient and low noise light storage in atomic ground states. In [5] we spectroscopically study Rb vapor in a high magnetic field under conditions of EIT and optical pumping, laying the ground for the memory implementation reported in [4].

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). Currently, the signal-to-noise ratio seems to be limited by the poor initial atomic polarization, caused by radiation trapping. After improving the initial atomic state preparation by optimizing the filling and geometry of the cell, interfacing attempts of the microfabricated memory with a single-photon source will be attempted. An optical interconnect with miniaturized memories would pave the road to more complex (room-temperature) networking applications, as, e.g. sharing entanglement across separate nodes.

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