Broadband Single-Photon Storage in a Scalable Quantum Memory

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Quantum networks enable long-distance entanglement distribution and the transfer of quantum information between remote nodes. Quantum memories interfaced with compatible single-photon sources form a key component of such networks. A reliable network requires memories that are scalable, broadband, and straightforward to implement. Owing to significant advances in atomic control techniques and the wafer-scale microfabrication of vapor cells, ground-state atomic vapor quantum memories have emerged as strong candidates for such applications [1]. However, two outstanding challenges have limited their practical utility: incompatibility with single-photon sources and read-out noise that degrades the quality of retrieved photons, as revealed by photon number statistics. Here, we exploit polarization selection rules in the hyperfine structure of spin-polarized atoms to suppress read-out noise and preserve the single-photon character of the retrieved light.

Previously, we reported the first successful storage of 370 MHz-bandwidth single photons — generated from a heralded single-photon source based on cavity-enhanced SPDC in ppKTP — in a quantum memory implemented in warm ^{87}Rb vapor [2,3], with $g^{(2)}_{c,ret} = 0.177(23)$ confirming the non-classical character of the retrieved photons. Subsequent technical improvements, including fast optical switching via a pulsed tapered amplifier and amplified chirped laser pulses [4], yielded a two-fold improvement in efficiency (from 1.11(2)% to 2.14(3)%), a storage lifetime of 1.67 µs, and a more pronounced non-classical retrieval with $g^{(2)}_{c,ret} = 0.135(17)$.

Building on these results, we will implement the quantum memory in a specially engineered capillary-shaped vapor cell. Compared to bulk cells, the capillary geometry is expected to maximise the overlap between the optical field and the atomic ensemble, ensuring more uniform atom addressing and enhanced light–matter interaction. Combined with the demonstrated technical improvements, this approach represents a viable route toward scalable, room-temperature quantum network nodes.

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References

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