SUPPORTING ONLINE MATERIAL
for
Atomic Memory for Correlated Photon States

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Experimental Details

The hyperfine coherence time is in practice limited by atoms moving out of the beam volume, and is enhanced with a buffer gas (we used cells with 3 and 4 torr Ne), resulting in spin-coherence lifetimes in the μs range. Two extended-cavity diode lasers provide the write and retrieve control beams. The control beams have typical powers of 0.7 mW (write) and 3.2 mW (retrieve) and are focused in the cell to diameters of about 0.5 mm. The relevant number of atoms interacting with the laser beams along the cell length is about 10^9–10^{10}. We observed spontaneous Raman signals for both linear and circular polarizations of the control beams. The write laser was typically tuned about $\Delta_W \sim 1$ GHz away from resonance with the $F = 1 \rightarrow F' = 2$ transition of the D_1 absorption line ($|g\rangle \rightarrow |e\rangle$ transition in Fig. 1A of the main text), while the retrieve laser was tuned near resonance with the $F = 2 \rightarrow F' = 2$ transition ($|s\rangle \rightarrow |e\rangle$ in Fig. 1A of the main text). The retrieve laser was also used for preparation of the atoms into the ground state $|g\rangle$ via optical pumping. We employed filters (based on diffraction gratings and crystal polarizers) following each laser to suppress the spontaneous emission background and spurious modes in the control beams. The intensities of these beams could be modulated with acousto-optic modulators. The two control beams largely overlap in the ^{87}Rb cell; a small angle (≈ 3 mrad) between these beams allows for spatially separated detection of the Stokes and anti-Stokes fields that co-propagate with the write and retrieve control beams, respectively. Filters following the vapor cell block the transmitted control beams such that only Raman fields reach the detectors. For different experimental circumstances, we used filters based on isotopically pure ^{85}Rb absorption cells or crystal polarizers. To detect the Raman fields we used home-built detectors based on high-efficiency low-capacitance Si photo-diodes placed in low current-noise transimpedance amplifier circuits. The measured quantum efficiency was about 88%. Scanning Fabry-Perot etalons and beatnote detection of the Raman fields in the presence of transmitted control beams (i.e., without the Raman filters) were used for identifying the Raman modes. In our experiments we only observed detectable Raman fields in narrow conical volumes around the control beams. This directionality is associated with a long pencil-shaped Raman gain medium (formed by the optically-pumped $|g\rangle$-state atoms dressed by the write beam), and is closely related to the concept of collective enhancement discussed in Ref. (*1*).

References and Notes

1. L. M. Duan, M. D. Lukin, J. I. Cirac, P. Zoller, *Nature* **414**, 413 (2001).