Efficient gradient echo memory in three-level atoms

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Quantum state storage is an important element in proposals for long distance quantum cryptography networks and quantum computing protocols. Many systems have been proposed in order to realise optical quantum memory. These include electromagnetically induced transparency (EIT), off-resonant Raman interactions, controlled reversible inhomogeneous broadening (CRIB), atomic frequency combs (AFC), and spin-polarization [1].

Our scheme is the Gradient Echo Memory that was developed by groups at the ANU for two-level systems [2, 3, 4]. In our experiments, we have adapted this scheme for three-level atomic ensembles and store light in the long-lived ground states of ^{87}Rb [5, 6]. This works in exactly the same way as the two level scheme, except now the two levels are the ground states of the three-level system. The ground states are coupled by a strong optical field that is far-detuned from resonance with the excited state, as shown in Fig.1(a). Our atomic ensemble is in a warm vapour cell (around 70 degrees) and contains a small amount of krypton buffer gas (0.5 Torr). A schematic diagram of our protocol is shown in Fig.1(b). The essential feature is the atomic frequency gradient that is linear over the length of the cell. After absorption, a pulse of light is recalled as a photon echo by reversing the sign of this gradient. In combination with manipulation of the coupling beam, it is also possible to recall pulses in arbitrary order from the memory [6], as well as manipulate the spectral properties of the echo [4].

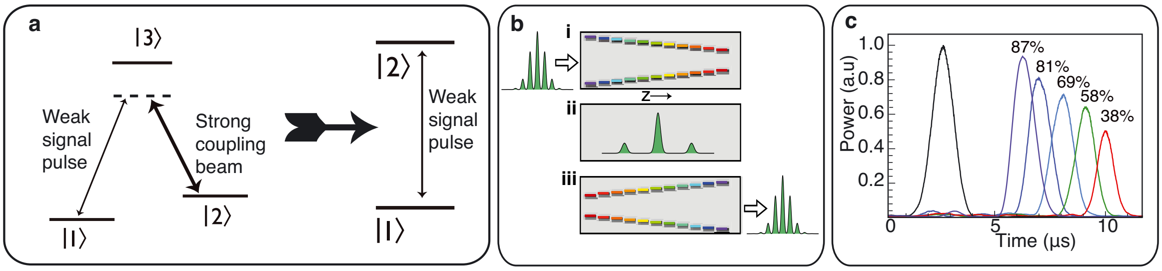

Fig. 1: a) The strong coupling field provides a quasi-two-level system for our memory. b) A pulse of light enters the medium (i) and due to the frequency gradient is decomposed into a Fourier spectrum spatially along the length of the ensemble (ii). After reversing the gradient an echo emerges (iii). c) The recall from our memory as a function of storage time.

The recall from our memory is highly efficient with up to 87% recall for storage times of one pulse-width [7]. This is the highest coherent recall ever measured from a quantum memory candidate. Our experiments suggest that the limitation to our efficiency is the atomic motion and residual scattering due to the strong control field, which is only a few Doppler widths away from resonance with the excited state. These problems may be addressed by using a cold atomic ensemble in, for example, an optical dipole trap.

References

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