Quantum memory using Gradient Echo and EIT

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We have investigated two quantum memory schemes, the Gradient Echo Memory (GEM) and Electromagnetically Induced Transparency (EIT). In the GEM scheme [1], light is stored in an ensemble of two-level atoms of long excited state decay time. By applying an external electric field, the energy levels of the atoms may be Stark shifted, providing a linear frequency shift along the storage medium. An incoming light pulse will then be absorbed, with each frequency component of the optical signal frozen in a different point along the storage medium. Upon inversion of the Stark shift, the dipoles reverse their evolution and rephase, causing the light to be re-emitted in the forward direction. This process is depicted in Figs. (a) to (c). Figure (d) shows the real part of the optical field as it enters the GEM system (top left) and then decays as it is stored in the optical coherence of the atoms. In the centre of the simulation, the Stark shift is reversed causing the optical field to gain strength and speed as leaves the storage medium. Our modelling has shown that this memory can be ideally efficient and can preserve the quantum state of the optical field without adding any extra quantum noise. Experiments with classical light pulses have demonstrated light storage using GEM [1].

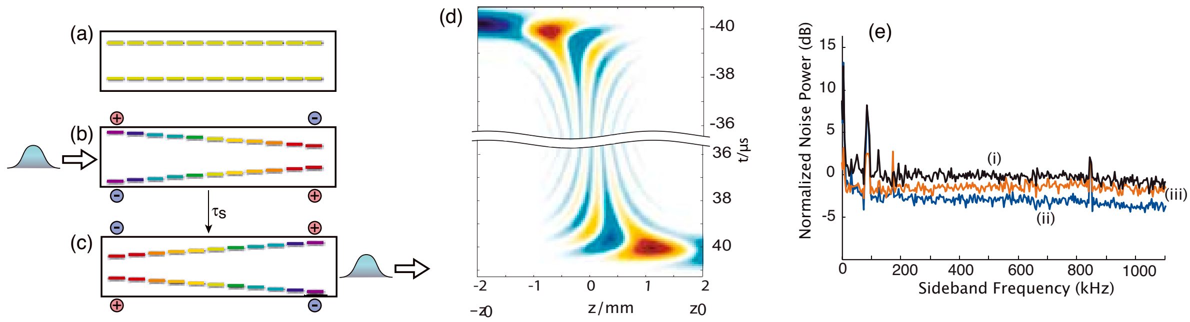

Figure 1: (a) An ensemble of two-level atoms used for GEM. (b) The Stark shifted atoms absorb all frequency components of a light pulse. (c) The reversal of the Stark shift releases the light. (d) The real part of the optical field as it is stored in the GEM. (e) Storage of squeezed light in EIT: (i) shot noise, (ii) squeezing after EIT and (iii) squeezing before EIT.

Our EIT work is both theoretical and experimental. Numerical and analytic quantum models of EIT have been used to investigate how well it performs as an optical quantum memory [2]. The modelling includes sources of quantum noise that degrade the performance of EIT. Any non-ideal system needs some criteria with which it may be characterised. To this end, we have proposed the use of quantum information criteria to quantify the performance of EIT. Experimentally, we have worked on the storage of squeezed states of light. Using the source of tuneable squeezed light developed in our labs [3], we have so far demonstrated a 2.2 μs delay of a squeezed state. Preliminary results are shown in Figure (e). Here, an initial squeezed state (iii) emerges still squeezed (ii) after transmission.

References

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