High fidelity quantum memories with dynamical switching

Q. Y. He, M. D. Reid, and P. D. Drummond
Centre for Atom Optics and Ultrafast Spectroscopy, ACQAO, SUT

We propose a digital approach to quantum memories using a single-mode oscillator-cavity model (Fig. 1(a)), in which the coupling is shaped dynamically in time to provide the optimum interface to an input pulse [1]. This concept, developed with partner investigator E. Giacobino in IFRAF (Paris) relies on the integration of a microscopic optical cavity with a long-lived quantum oscillator. The key new approach is a tailored gating pulse, which matches the memory to an input mode.

Our generic model is applicable to any linear storage medium ranging from a superconducting device to an atomic medium. In a subsequent paper, we derived a condition on the time-dependence of the oscillator-cavity coupling required to match to any external pulse-shape, including time-symmetric pulses (Fig. 1(b)). This contrasts with our previous work [1], in which the coupling was a step function resulting in non-symmetric pulses. Our digital quantum memory proposal is highly suitable for single qudit quantum information processing.

An essential feature of our treatment is that we show how a smooth, time-symmetric sech-pulse can be stored for times longer than the pulse duration, and recalled with high quantum fidelity. Thus, the output pulse shape replicates the input pulse. This type of quantum memory promises to give both high quantum fidelity and long lifetimes.

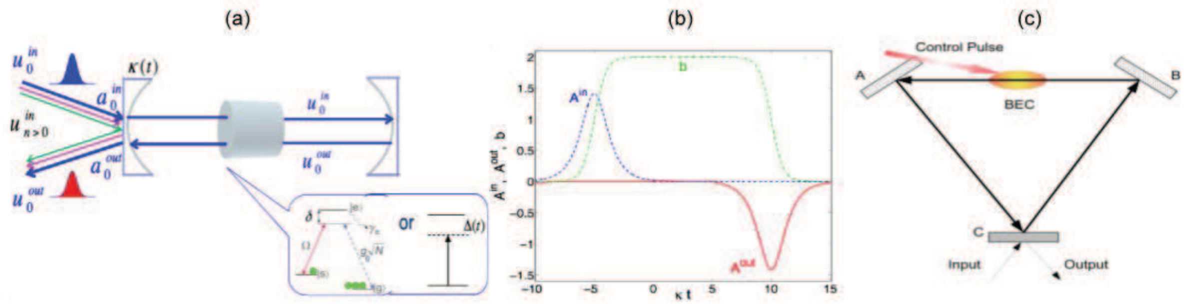

Fig. 1: (a) Proposed dynamical atom-cavity QM; (b) Cavity input (dashed) and output (solid) amplitudes [1]; (c) Setup for the memory with Bose-Einstein condensation [3].

The proposed architecture is very adaptable to many different technologies. These range from ultra-cold atomic gases at micro or nano-Kelvin temperatures through to superconducting circuits and even cooled nano-mechanical oscillators, which can approach the quantum domain. In principle, any of these can be utilized for the storage component inside the optical cavity. Currently, we are working on the storage of information in a trapped BEC [3]. The setup for the quantum memory is illustrated in Fig. 1(c). Here, we consider a BEC trapped in an optical cavity, which is continuously driven by a control laser. BEC in a cavity has been recently realized in experiments. This system results in very strong atom-photon coupling. This is extremely useful for performing quantum information processing before decoherence sets in. It also has the potential for new tests of quantum mechanics using entanglement of massive particles.

References

[1] Q. Y. He, M. D. Reid, E. Giacobino, J. Cviklinski, and P. D. Drummond, Phys. Rev. A **79**, 022310 (2009).
[2] Q. Y. He, M. D. Reid, and P. D. Drummond, Optics Express **17**, 9662 (2009).
[3] H. D, Q. Y. He, M. D. Reid, H. Dong and P. D. Drummond, in preparation.