Rephasing-based solid state quantum memory

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A quantum coherence control is applied to photon echoes to extend storage time and to eliminate population inversion-caused spontaneous emission noises. Photon echoes have intrinsic storage properties of multimode in time, frequency, and space domains. The writing time or storage bandwidth is determined by inhomogeneous broadening of the medium, where it is normally far beyond GHz in doped solids. Due to the rephasing mechanism of the inhomogeneously broadened atoms or ions, the storage mechanism is based on the reversibility of collective atoms’ rephasing. However, this rephasing property causes a population inversion to the echoes resulting in quantum noises via spontaneous or stimulated emission processes. Another intrinsic drawback of the original photon echoes for the applications of quantum memories is a short storage time limited by atom’s phase decay time, normally far less than a millisecond, where quantum Repeaters need a much longer storage time in the orders of seconds or minutes. In this talk I present a novel technique to eliminate the π-pulse-caused quantum noises via double rephrasing technique [1]. I also present an optical locking method to extend the storage time by applying quantum coherence control for the coherence swapping between optical and spin states [2,3]. Moreover, by adapting the three-pulse photon echo property of population grating as a storage mechanism, the final storage time can be extended to spin population decay time, which is far beyond a second. Thus, this work can be applied for ultralong quantum memories needed for quantum Repeaters at long-distance quantum communications. Preliminary experimental demonstrations are shown as a proof of principle of the ultralong quantum memory protocol [4].

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