All-Optical Quantum Storage Based on Spatial Chirp of the Control Field

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Figure 1: Energy diagram of the off-resonant Raman interaction in a three-level \textit{Λ} system. The angular frequencies of the signal and control fields are $\omega_s$ and $\omega_c$, respectively. The control field spectrum width is given by the spatial chirp $\Delta \omega_c$, which is $\beta L$ for the transverse excitation setup. (b, c) Storage and retrieval for transverse excitation setup in which the propagation directions of the signal and control fields are perpendicular to each other.

We suggest an all-optical quantum memory scheme which is based on the off-resonant Raman interaction of a signal quantum field and a strong control field in a three-level atomic medium in the case where the control field has a spatially varying frequency across the beam, called a spatial chirp (Fig. 1). We show that the effect of such a spatial chirp is analogous to the effect of an artificial inhomogeneous broadening of the atomic transition. So in the regime of continuous spatial chirp \cite{1}, our scheme is equivalent to gradient echo memory. The proposed scheme can also operate in the regime of discrete spatial chirp \cite{2}, which resembles atomic frequency comb and allows for the realization of single photon processing.

The proposed scheme does not require temporal modulation of the control field or the atomic levels, neither the existence of a broad inhomogeneous broadening profile. It can be realized without additional electric or magnetic fields. This means that materials demonstrating neither linear Stark nor Zeeman effects can be used and/or materials which are placed in specific external fields remain undisturbed.

References

\cite{1} X Zhang, A Kalachev, and O Kocharovskaya, Phys. Rev. A \textbf{90}, 052322 (2014)

\cite{2} X Zhang \textit{et al.}, in preparation