Control field absorption in superluminal propagation

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Pulse propagation with superluminal group velocities is widely studied phenomenon. In the analysis of these effects, however, the emphasis is often put on the signal (probe) pulse distortion assuming that the control field is constant along the direction of propagation. The omission of the control field absorption, which also propagates in the medium, neglects effects associated with decreasing amplitude of this field that affects reduction of the superluminal effects (changing the regime of propagation into the subluminal one) and closing the transparency window for the probe field simultaneously. In this paper we will demonstrate the influence of intensity variation of control fields (due to absorption along the propagation distance) on the signal pulse propagation in atomic media where superluminality is obtained by the use of an incoherent pump.

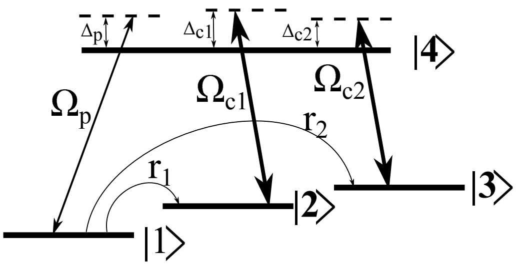

FIG. 1. Energy levels and couplings scheme of the considered tripod system.

The medium filled with atomic vapor in the tripod configuration will be considered as shown in the figure 1. Ω_p, Ω_{c1} and Ω_{c2} are the Rabi frequencies of the probe E_p, first control E_{c1} and second control E_{c1} fields respectively. r_1 and r_2 are the incoherent pumps.

The electric susceptibility of the system

$$\chi\left(\Delta_p\right) = \frac{N d_{14} \sigma_{41}}{\epsilon_0 \mathcal{E}_p^+},$$

where $\mathcal{E}_p^+$ is the Fourier transform of the probe field envelope is obtained by a numerical solution of the von Neumann equations for the density matrix of this atomic system in the *RWA Approximation* and the following relation

Typical plot of the electric susceptibility is drawn in the figure 2.

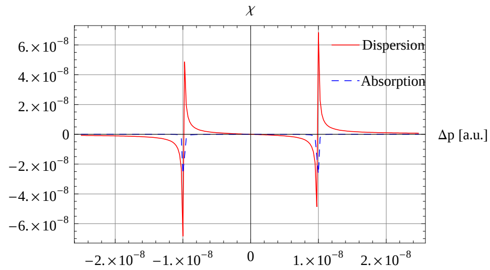

FIG. 2. Typical electric susceptibility of the considered system in the superluminal regime for $v_g = 139.5$ a.u.. Red solid curve represents dispersion, blue dashed curve is absorption.

To determine how the amplitude of the control field changes, one has to solve the equation of propagation which in the *SVEA Approximation* is given by the following formula

$$\frac{\partial \mathcal{E}_{ci}^-}{\partial z} = -\frac{i\omega_c N d_{4(i+1)} \sigma_{(i+1)4}}{2c\epsilon_0}.$$

Numerical results for the control field amplitude are shown in the figure 3.

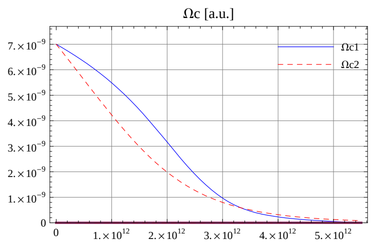

FIG. 3. First (blue solid curve) and second (red dashed curve) control field propagation. Note that at a distance of a few centimeters (typical length of the tested samples) decrease of the intensity of the control field is negligible, so that the superluminal effect does not disappears entirely.

Analysis of propagation of the probe field will be presented taking into account the absorption of the control field in the superluminal medium.

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