Coherent interaction of laser pulses in a resonant optically dense extended medium under the regime of strong field-matter coupling August 28, 2003

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abstract

Nonstationary pump-probe interaction between short laser pulses propagating in a resonant optically dense coherent medium is considered. A special attention is paid to the case, where the density of two-level particles is high enough that a considerable part of the energy of relatively weak external laser-fields can be coherently absorbed and reemitted by the medium. Thus, the field of medium reaction plays a key role in the interaction processes, which leads to the collective behavior of an atomic ensemble in the strongly coupled light-matter system. Such behavior results in the fast excitation interchanges between the field and a medium in the form of the optical ringing, which is analogous to polariton beating in the solid-state optics. This collective oscillating response, which can be treated as successive beats between light wave-packets of different group velocities, is shown to significantly affect propagation and amplification of the probe field under its nonlinear interaction with a nearly copropagating pump pulse. Depending on the probe-pump time delay, the probe transmission spectra show the appearance of either specific doublet or coherent dip. The widths of these features are determined by the density-dependent field-matter coupling coefficient and increase during the propagation. Besides that, the widths of the coherent features, which appear close to the resonance in the broadband probe-spectrum, exceed the absorption-line width, since, under the strong-coupling regime, the frequency of the optical ringing exceeds the rate of incoherent relaxation. Contrary to the stationary strong-field effects, the density- and coordinate-dependent transmission spectra of the probe manifest the importance of the collective oscillations and cannot be obtained in the framework of the single-atom model.