Compression of an intensive light pulse in photonic-band-gap structures with a dense resonant medium

Denis V. Novitsky*

B.I. Stepanov Institute of Physics, National Academy of Sciences of Belarus, Nezavisimosti Avenue 68, 220072 Minsk, Belarus

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Intensive light pulse interaction with a dense resonant medium is considered. The possibilities of optical switching and pulse compression at realistic parameters of the medium are analyzed. Pulse-shape transformation in different photonic-band-gap structures containing a dense resonant medium is studied. In particular, the effect of dispersion compensation due to nonlinear interaction with a medium is reported. The possibility of pulse control with another pulse is considered in the schemes of copropagating and counterpropagating pulses. It is shown that a photonic crystal makes controlling more effective, at least in the case of copropagating pulses.

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I. INTRODUCTION

The model of resonant two-level medium is studied actively for many decades (see, for example, [1,2]). This interest is caused, in many respects, by the possibility of ultrashort pulses generation which can be used in different fundamental and practical applications. The concept of the so-called dense resonant media implies the necessity of taking into account the interaction of an atom with local field produced by all other particles of the system. In other words, one has to consider near dipole-dipole (NDD) interactions which are characterized by the quantity

$$b = \frac{4\pi\mu^2 C}{3\hbar\gamma_2}, \tag{1}$$

where μ is the transition dipole moment, C is the volume density of two-level atoms, $\gamma_2 = 1/T_2$ is the rate of transverse relaxation, and $\hbar$ is the Planck constant. Nonlinear effects connected with NDD interactions become noticeable when the medium is dense enough. One of them, the effect of intrinsic optical bistability (IOB), was studied in detail [3–6]. It was shown that IOB occurs when b is greater than 4 (in the case of thin films [7]) or even less (if we consider propagation effects in extended medium [8]). This phenomenon takes place in the steady state, while in the pulse regime one can observe optical switching [9,10] and soliton formation [11,12]. In the present paper we also consider intensive light pulses so that change in the population difference (or inversion) cannot be neglected. To study pulse propagation, the numerical solution of the Maxwell wave equation was implemented. This allows us to automatically take into consideration the processes of dispersion and diffraction which are usually ignored in the analytical approaches.

The main attention in this research is devoted to discussion of the properties of a combination of a one-dimensional photonic crystal and a dense resonant medium under pulse operation. The stationary bistable response of such a system was analyzed previously [8]. It turned out that one can change and control such characteristics of bistability as hysteresis loop width and switching intensity by using photonic crystal. In the present paper pulse form transformation in such nonlinear photonic-band-gap (PBG) structures is studied in comparison with the behavior in the linear case. In particular, possibilities to compensate dispersion spreading in such a system and control pulse properties by using another pulse are expected to be found.

The paper is divided into several sections. In Sec. II the main expressions for description of the system considered are given, just as brief characterization of the numerical approach used. This methodology is then applied to obtain the results of the other sections. Section III is devoted to optical switching and pulse-shape change (compression and splitting) under propagation in a finite layer of a dense resonant medium. In particular, the role of near dipole-dipole interactions is estimated. Section IV contains the calculation results for a single pulse in a nonlinear photonic crystal, such as possibility of dispersive spreading compensation. Finally, in Sec. V two schemes of controlling pulse intensity with another pulse are considered. Photonic crystal is studied as an element which makes this process more effective, at least in the scheme of copropagating pulses.

II. BASIC EQUATIONS AND NUMERICAL APPROACH

Let us consider radiation propagation in a dense resonant medium in the z direction. Light interaction with resonant medium with taking into account nonlinear contribution due to near dipole-dipole interactions is described by the modified Maxwell-Bloch system as follows [13,14]:

$$\frac{dP}{dt} = \frac{i\mu}{\hbar}EN + iP\left(\Delta\omega + \frac{4\pi\mu^2 C}{3\hbar}N\right) - \gamma_2 P, \tag{2}$$

$$\frac{dN}{dt} = 2\frac{i\mu}{\hbar}(E^*P - P^*E) - \gamma_1(N-1), \tag{3}$$

$$\frac{\partial^2\Sigma}{\partial z^2} - \frac{1}{c^2}\frac{\partial^2\varepsilon_{\mathrm{bg}}\Sigma}{\partial t^2} = \frac{4\pi}{c^2}\frac{\partial^2 P_{\mathrm{nl}}}{\partial t^2}, \tag{4}$$

*dvnovitsky@tut.by

where N is the population difference, P is the microscopic (atomic) polarization, $\Delta\omega$ is the detuning of the field frequency ω from atomic resonance, $\gamma_1=1/T_1$ is the rate of longitudinal relaxation, and c is the light speed in vacuum. Macroscopic electric field Σ is expressed via its amplitude E as $\Sigma=E\exp[-i(\omega t-kz)]$; similarly for macroscopic nonlinear polarization we have $P_{\mathrm{nl}}=\mu CP\exp[-i(\omega t-kz)]$. Here $k=\omega/c$ is the wave number and $\varepsilon_{\mathrm{bg}}$ is the background dielectric permittivity, assumed to be linear and dispersionless.

The system of Eqs. (2)–(4) can be represented in the dimensionless form by introducing new arguments $\tau=\omega t$ and $\xi=kz$,

$$\frac{dP}{d\tau}=i\Omega N+iP(\delta+\epsilon N)-\tilde{\gamma}_2 P, \tag{5}$$

$$\frac{dN}{d\tau}=2i(\Omega^* P-P^*\Omega)-\tilde{\gamma}_1(N-1), \tag{6}$$

$$\begin{aligned}\frac{\partial^2\Omega}{\partial\xi^2}-\varepsilon_{\mathrm{bg}}\frac{\partial^2\Omega}{\partial\tau^2}+2i\frac{\partial\Omega}{\partial\xi}+2i\varepsilon_{\mathrm{bg}}\frac{\partial\Omega}{\partial\tau}+(\varepsilon_{\mathrm{bg}}-1)\Omega\\ =3\epsilon\left(\frac{\partial^2P}{\partial\tau^2}-2i\frac{\partial P}{\partial\tau}-P\right),\end{aligned} \tag{7}$$

where $\Omega=(\mu/\hbar\omega)E$ is the dimensionless amplitude of electric field (normalized Rabi frequency); $\delta=\Delta\omega/\omega$ is the normalized frequency detuning; $\epsilon=4\pi\mu^2C/3\hbar\omega=\tilde{\gamma}_2 b$ is the NDD interaction constant which provides extra nonlinearity in Eq. (5); $\tilde{\gamma}_j=\gamma_j/\omega$, $j=1,2$.

Numerical solving of the system of Eqs. (5)–(7) is performed using the finite-difference time-domain (FDTD) method. The explicit scheme to solve Eq. (7) on the computational mesh $(l\Delta\tau,j\Delta\xi)$ is given by

$$\Omega_j^{l+1}=[-a_1\Omega_j^{l-1}+b_1\Omega_{j+1}^l+b_2\Omega_{j-1}^l+f\Omega_j^l-R]/a_2, \tag{8}$$

where

$$a_1=\varepsilon_j(1+i\Delta\tau),\quad a_2=\varepsilon_j(1-i\Delta\tau),$$

$$b_1=\left(\frac{\Delta\tau}{\Delta\xi}\right)^2(1+i\Delta\xi),\quad b_2=\left(\frac{\Delta\tau}{\Delta\xi}\right)^2(1-i\Delta\xi),$$

$$f=2\varepsilon_j-2\left(\frac{\Delta\tau}{\Delta\xi}\right)^2+\Delta\tau^2(\varepsilon_j-1),$$

where ε_j is the value of dielectric permittivity $\varepsilon_{\mathrm{bg}}$ at $\xi_j=j\Delta\xi$. In Eq. (8) R stands for the finite-difference representation of the right-hand member of Eq. (7) which describes nonlinear properties of the medium. For the case of the dense resonant medium it is

$$R=3\epsilon[P_j^{l+1}(1-i\Delta\tau)+P_j^{l-1}(1+i\Delta\tau)-P_j^l(2+\Delta\tau^2)].$$

Polarization in the mesh points is obtained from Eqs. (5) and (6). To solve them the well-known midpoint trapezoidal method is used. To set the boundary conditions we apply the TF/SF approach, when the full calculation region is divided into two subregions containing total (TF) and scattered (SF) fields, respectively, and the so-called absorbing boundary conditions according to the perfectly matched layer (PML) method. This approach helps us to avoid nonphysical reflections of the scattered field back into the calculation region [15]. The calculation scheme considered is similar to that of Ref. [14] where it was used to analyze validity of the quasiadiabatic approximation for consideration of ultrashort light pulses propagation in a dense resonant medium.

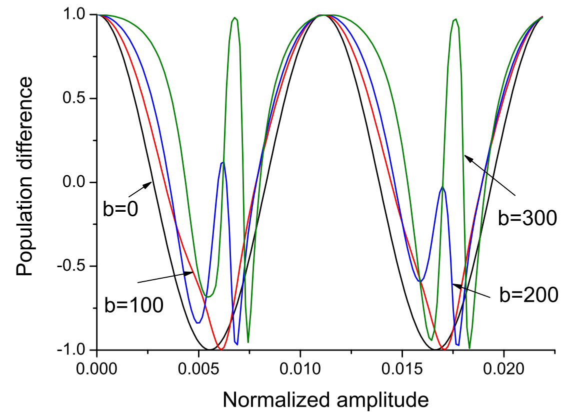

FIG. 1. (Color online) Population difference on the entrance of the layer of the dense resonant medium after pulse passage versus its amplitude Ω_0 at different values of NDD interaction constant. Layer thickness $L=\lambda$.

III. COHERENT PULSE INTERACTION WITH A DENSE RESONANT MEDIUM

As it is known, the cases of coherent and incoherent interactions are distinguished by the comparison of the pulse duration t_p with the characteristic relaxation times of the media T_1 and T_2; moreover, as a rule, $T_1>T_2$. Here we consider the coherent case when $t_p\ll T_2<T_1$. In this section the values of parameters are assumed to be as follows: light wavelength $\lambda=0.5$ μm, $t_p=30$ fs, $T_1=1000$ ps, $T_2=100$ ps, $\delta=0$, and, if not stated another, $\varepsilon_{\mathrm{bg}}=1$. The pulse on the entrance of the medium has Gaussian shape $E=E_0\exp(-t^2/2t_p^2)$. Obviously, in time intervals comparable with the pulse duration (of the order of 0.1 ps) the processes of incoherent relaxation can be neglected. Under these conditions the system consisting of two-level atoms can demonstrate optical switching from the ground state to the excited one for the time of the order of the pulse duration [9]. However, as the authors of Ref. [10] note, taking into account for the propagation effects (hence, self-phase modulation as well) not only changes the characteristics of switching but also makes it difficult to qualitatively predict them without execution of rigorous numerical simulations in every particular case.

The calculation results in Fig. 1 show that, at small values of the NDD interaction constant b, the dependence of population difference on the pulse amplitude has periodic form. When the parameter of extra nonlinearity b is increased, this strictly periodic situation is disturbed, inversion maximum being shifted toward greater amplitudes and even being reduced, requiring more accurate adjustment of pulse intensity. In addition, there is similar dependence on the layer thick-

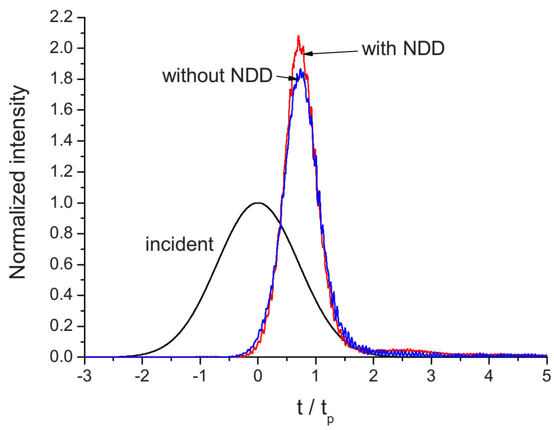

FIG. 2. (Color online) Calculation results for pulse propagation through the layer of the dense resonant medium. The amplitude of pulse is $\Omega_0=1.5\Delta\Omega_T$. The thickness of the layer $L=\lambda$; NDD interaction parameter $b=2000$.

ness: strictly periodic behavior of population difference occurs only at small (as compared with wavelength) medium thickness.

The difficulties of optical switching, noted in Ref. [10], are connected with the features considered above, as they have analyzed the case of large values of NDD interaction constant. In our designation it corresponds to the values of b of the order of hundreds and thousands. It seems not to be realistic: usually b does not exceed several units. For example, for gaseous media with typical parameters $\mu^2=10^{-38}$ erg cm^3, $\gamma_2=10^9$ s^{-1}, and $C=10^{20}$ s m^{-3} [5,16] one obtains $b\approx 4$. In the case of excitonic media possessing substantially greater dipole moment ($\mu^2=10^{-36}$ erg cm^3, $\gamma_2=10^{10}$ s^{-1}, and $C=10^{18}$ s m^{-3} [12]) we have only $b\approx 0.4$. The dramatic increase in the parameter of NDD interaction is unlikely to expect. In the present paper we keep to this restriction so the periodic behavior corresponding to small values of b will be always valid.

This implies that the effect of NDD interaction on pulse propagation in a dense resonant medium is not significant at realistic parameters. To directly ascertain this conclusion, one should compare the results of the calculations when the term including parameter b is present or absent in Eq. (2) or (5). It turned out that the results remain the same in both cases. It seems to be obvious if we recall that the parameter b amounts to several units (at best, $b=10$). This corresponds to the utterly small value of $\epsilon\approx 1\times10^{-4}-1\times10^{-5}$ in normalized Eq. (5). Only when the NDD interaction constant takes on sufficiently large values, the contribution of this term becomes essential (Fig. 2). Thus, while in stationary regime NDD interaction plays vital role in such nonlinear phenomena as intrinsic optical bistability [8], for coherent pulse propagation this influence seems to be negligible, at least for realistic values of parameters.

Since the influence of NDD interactions is negligible, one can estimate the period $\Delta\Omega_T$ of the dependence shown in Fig. 1 by using the commonly known concept of pulse area [2],

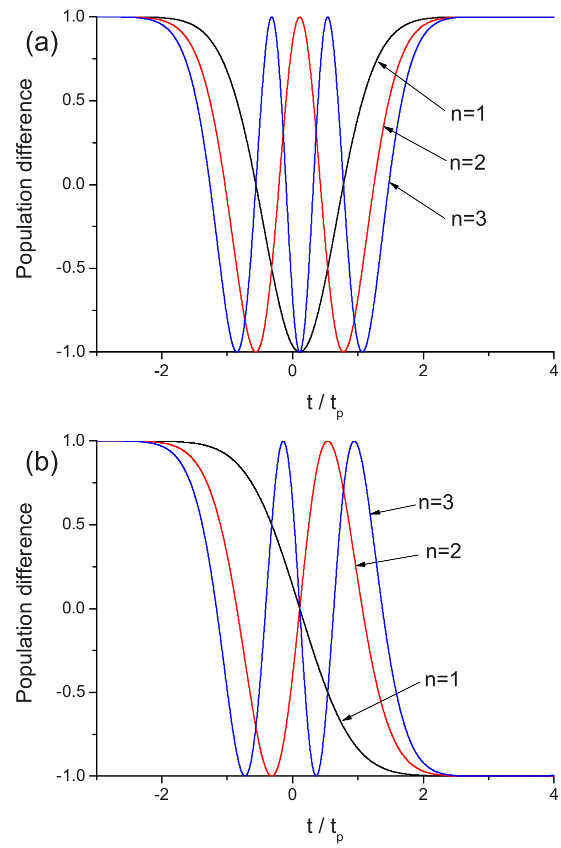

FIG. 3. (Color online) Temporal behavior of population difference on the entrance of the layer of the dense resonant medium at the amplitude of the pulse: (a) $\Omega_0=n\Delta\Omega_T$ and (b) $\Omega_0=(n-1/2)\Delta\Omega_T$. Parameter $b=1$.

$$\vartheta = 2\frac{\mu}{\hbar}\int_{-\infty}^{\infty} E dt. \tag{9}$$

The period $\Delta\Omega_T$ corresponds to the pulse which returns atoms after excitation exactly into the ground state. The area of such a pulse should be equal to 2π. Thus, for Gaussian pulse we obtain

$$\Delta\Omega_T = \frac{\lambda}{2\sqrt{2\pi}ct_p}. \tag{10}$$

For the case considered (Fig. 1) it is approximately $\Delta\Omega_T\approx 0.011$. If the amplitude of the incident pulse amounts to an integer number of these periods, i.e., $\Omega_0=n\Delta\Omega_T$, $n=1,2,3,\ldots$, then in temporal behavior of population difference [Fig. 3(a)] one can observe n minima and $n-1$ maxima before it achieves a stationary level, in this instance corresponding to the ground state of the system ($N=1$). In turn, at $\Omega_0=(n-1/2)\Delta\Omega_T$ $n-1$ maxima and minima occur [Fig. 3(b)] before the medium becomes inverted ($N=-1$). However, this final value of population difference after pulse passage is not stable, as far as relaxation to the ground state becomes apparent at longer time intervals. It proceeds the faster, the greater constant b (Fig. 4). Obviously, incoherent relaxation does not have enough time to appear. Therefore

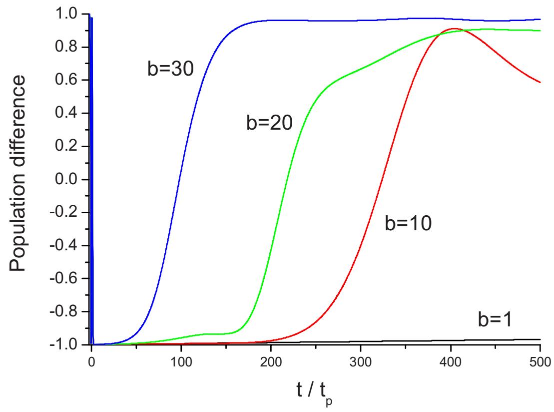

FIG. 4. (Color online) Temporal behavior of population difference on the entrance of the layer of the dense resonant medium at different values of the parameter b. The amplitude of the pulse is $\Omega_0=1.5\Delta\Omega_T$.

one can attribute this effect to nonlinear interaction of radiation with the resonant medium. Moreover, this relaxation process should be apparent in spatial scale, giving rise to nonuniform distribution of population difference along the layer thickness (Fig. 5). The similar behavior also takes place at smaller values of b, but significantly larger thicknesses of the layer.

Since the influence of NDD interactions is negligible, the formation of stationary pulses (solitons) of hyperbolic secant (sech) shape can be expected. At the same time energy conservation, area change, and shape transformation (from Gaussian to hyperbolic secant) may cause the pulse to become shorter and more intensive. However, this process is limited by diffraction and dispersion of light: the pulse begins to spread as it propagates in the medium. This fact is the reason of occurrence of the length of optimal pulse compression. In Fig. 6 it amounts to about 120λ. Note that, after reaching this first maximum, several others are observed: at $L\approx 450\lambda$ [Fig. 6(b)], $L\approx 700\lambda$, and $L\approx 900\lambda$ [Fig. 6(c)]. Finally, at certain (sufficiently large) distance the pulse exhibits ultimate attenuation and decay [Fig. 6(d)].

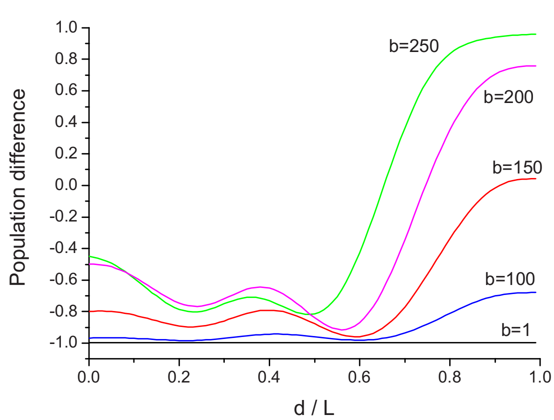

FIG. 5. (Color online) Distribution of population difference along the thickness $L=\lambda$ of the layer of the dense resonant medium at different values of the NDD interaction parameter. The amplitude of the pulse is $\Omega_0=1.5\Delta\Omega_T$.

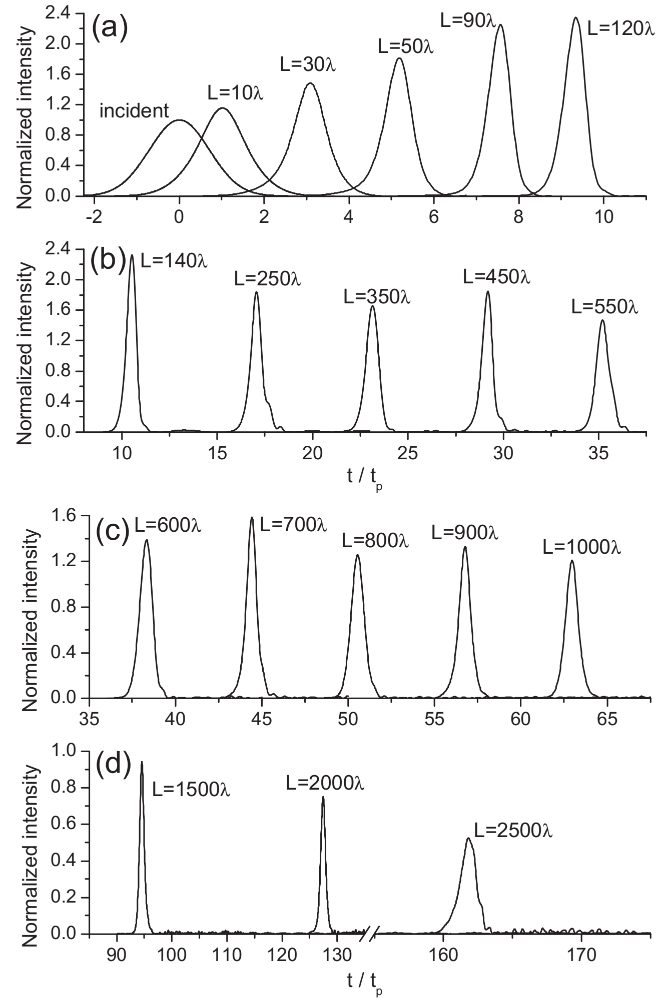

FIG. 6. Pulse form transformation after propagation through the layer of the dense resonant medium of different thicknesses. The amplitude of pulse is $\Omega_0=1.5\Delta\Omega_T$. NDD interaction parameter $b=10$.

Another important effect that can be observed in this system is the pulse splitting into several components. The number of components depends on the area of initial pulse. For example, if the amplitude of the pulse is $\Omega_0=2\Delta\Omega_T$ (area equals 4π), it undergoes splitting into two ones (Fig. 7) corresponding to two 2π pulses. The second (low-intensive) pulse retards more and more from the first one as they propagate in the medium. Simultaneously both these pulses lose energy with distance due to diffraction and dispersion.

IV. SINGLE PULSE IN PHOTONIC CRYSTAL WITH A DENSE RESONANT MEDIUM

As it was already stated, the changes in laser-pulse characteristics under propagation in nonlinear PBG structures are of special interest in the present paper. The one-dimensional photonic crystal to be considered here is a sequence of two alternating layers with different thicknesses and background refractive indices (furthermore, they are assumed to equal $n_1=1$ and $n_2=3.5$). The thickness of the first layer is

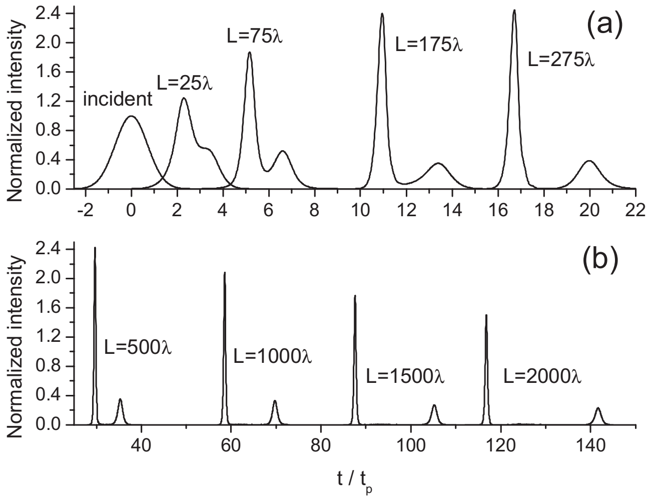

FIG. 7. Pulse form transformation after propagation through the layer of the dense resonant medium of different thicknesses. The amplitude of pulse is $\Omega_0 = 2\Delta\Omega_T$. NDD interaction parameter $b = 10$.

$d_1 = 0.4\ \mu$m, while the second one, d_2, is treated as a variable parameter which allows to change spectral characteristics of the periodic structure. The reflection spectra for different values of d_2 are shown in Fig. 8(a). They are plotted in the vicinity of the main wavelength $\lambda = 0.5\ \mu$m. The pulse amplitude in this section is considered to be equal to $\Omega_0 = 1.5\Delta\Omega_T$.

Light pulse propagation in photonic crystals, possessing strong dispersion due to periodic variation in optical properties, results in their spreading on large distances. As it is known [17,18], for materials with sufficiently strong nonlinearity, the competition between dispersion and nonlinear interaction leads to effective compression of pulses. These results regard media with Kerr-type nonlinearities. Here we consider some properties of the systems combining PBG structure with the dense resonant medium (the value of the NDD interaction constant is $b = 10$).

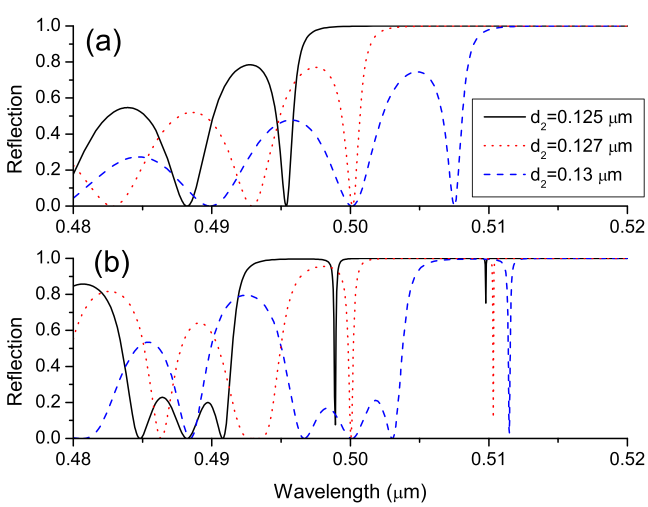

FIG. 8. (Color online) Reflection spectra of photonic crystal (number of periods 8) for different values of the thickness d_2: (a) without a defect, (b) with a defect of $L = 20\lambda$ and $n_3 = 1$.

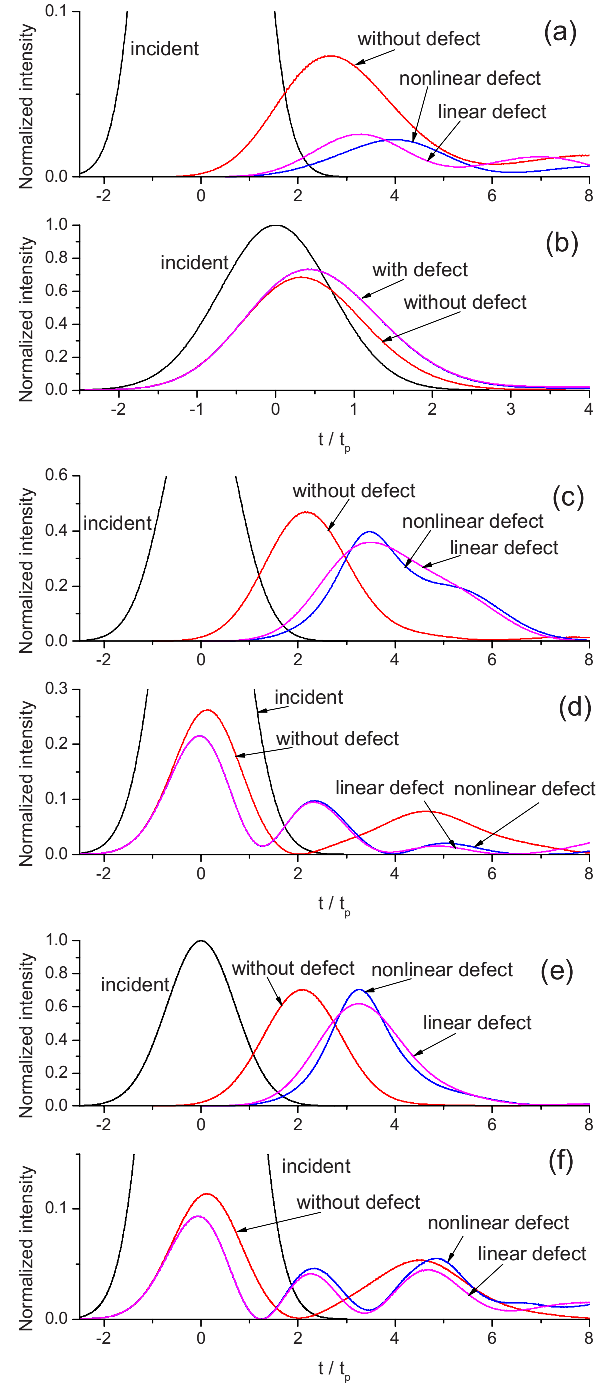

FIG. 9. (Color online) The forms of transmitted [(a), (c), (e)] and reflected [(b), (d), (f)] pulses after interaction with the photonic crystal (number of periods 8) with a defect layer of thickness $L = 20\lambda$, $n_3 = 1$, $b = 10$. The thickness d_2 is variable: [(a), (b)] $d_2 = 0.125$, [(c), (d)] $d_2 = 0.127$, [(e), (f)] $d_2 = 0.13\ \mu$m.

The first such system is a structure containing a defect layer in the middle of a sequence of alternating layers. The reflection spectrum of a such system with the linear defect (the refractive index n_3 is unity) is shown in Fig. 8(b). The well-known feature of the photonic crystals with defects is seen: appearance of the defect modes, i.e., narrow spectral peaks in the band gap. Figure 9 demonstrates the computa-

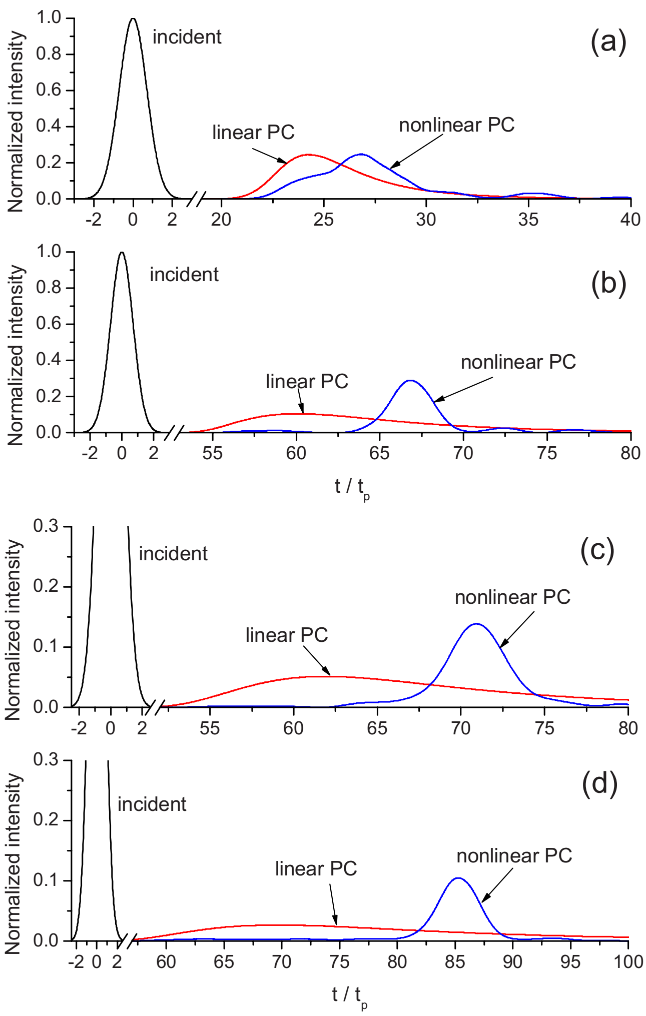

FIG. 10. (Color online) The forms of transmitted pulses after interaction with the photonic crystal with linear and nonlinear layers d_1 ($n_1=1$, $b=10$). The number of periods is (a) 100, [(b), (c), (d)] 250. The thickness d_2 is variable: [(a), (b)] $d_2=0.13$, (c) $d_2=0.127$, (d) $d_2=0.1285$ μm.

tion results of pulse transmission and reflection for linear and nonlinear defect layers. As transmission of the PBG structure increases (as d_2 changes), the effect of nonlinear interaction on the pulse shape becomes stronger, leading to more effective compression [Fig. 9(e)]. As to reflected radiation, there are several pulses—the first one being reflected directly from the photonic crystal layers. The others were reflected after interaction with the dense resonant medium.

It seems to be more interesting to consider a variant when the layers of photonic crystal are nonlinear. Figure 10 gives the simulation results when the layers d_1 of the PBG structure are filled with the dense resonant medium. It is seen that use of nonlinear layers allows to effectively compensate dispersive spreading of pulse occurring in the case of linear photonic crystal. Different values of the layer thickness d_2 correspond to different values of reflectivity of the linear structure for the radiation wavelength $\lambda=0.5$ μm (Fig. 11). Naturally, more intensive transmitted pulse is observed for smaller reflectivity (when $d_2=0.13$). At the same time, position of wavelength with respect to PBG spectrum influences

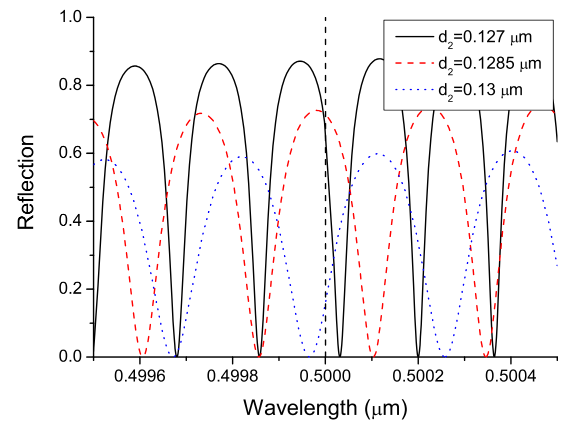

FIG. 11. (Color online) Reflection spectra of photonic crystal (number of periods 250) for different values of the thickness d_2.

the duration of pulse transmission through the system: the smaller reflectivity of the structure considered, the shorter time interval required for the pulse to appear on its output. Comparing transmission durations in Figs. 10(a)–10(c), one can note that radiation needs only about $67t_p$ for $d_2=0.13$ μm, while for $d_2=0.1285$ μm (the largest reflectivity) this pulse delay is equal to $85t_p$.

Finally, we consider another system when both layers of photonic crystal are nonlinear. On the whole, the behavior of the system (Fig. 12) remains approximately the same as in previous case. The maximal change occurs for the pulse at $d_2=0.1285$ μm: the peak intensity decreases, while the time delay increases. Note that at $d_2=0.13$ μm the effective splitting of the pulse is observed. It may be connected with the change in reflection characteristics of the nonlinear PBG structure under consideration.

Thus, interaction of light pulse with nonlinear PBG structure leads to effective compensation of dispersive spreading. On the other hand, the use of photonic crystals allows us to control intensity and time retardation of transmitted pulse. Additional possibilities to control pulse properties are connected with the use of the second one.

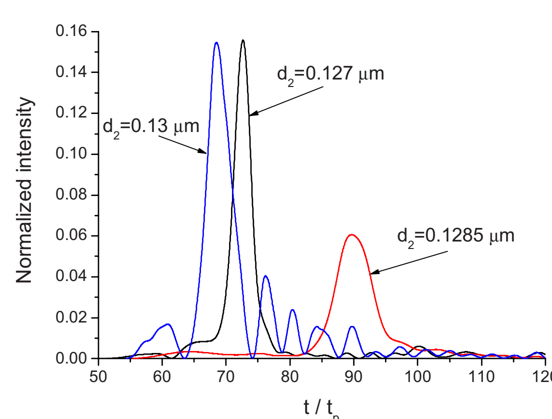

FIG. 12. (Color online) The forms of transmitted pulses after interaction with the photonic crystal (number of periods 250) with both nonlinear layers ($n_1=1$, $n_2=3.5$, $b=10$) for different thicknesses d_2.

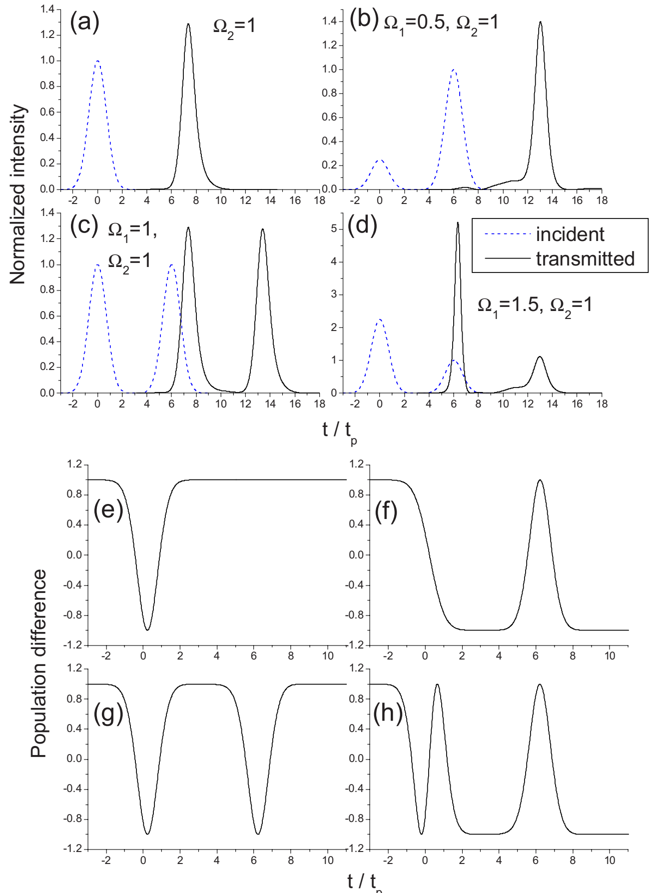

FIG. 13. (Color online) [(a)–(d)] Pulse forms and [(e)–(h)] corresponding population difference dynamics on the entrance of the medium. Intensity of the first pulse [(b), (f)] Ω_1=0.5, [(c), (g)] Ω_1=1, [(d), (h)] Ω_1=1.5, while for the second one Ω_2=1. Pictures (a), (e) are for the case of single pulse Ω_2=1. Other parameters: L=100λ, b=10.

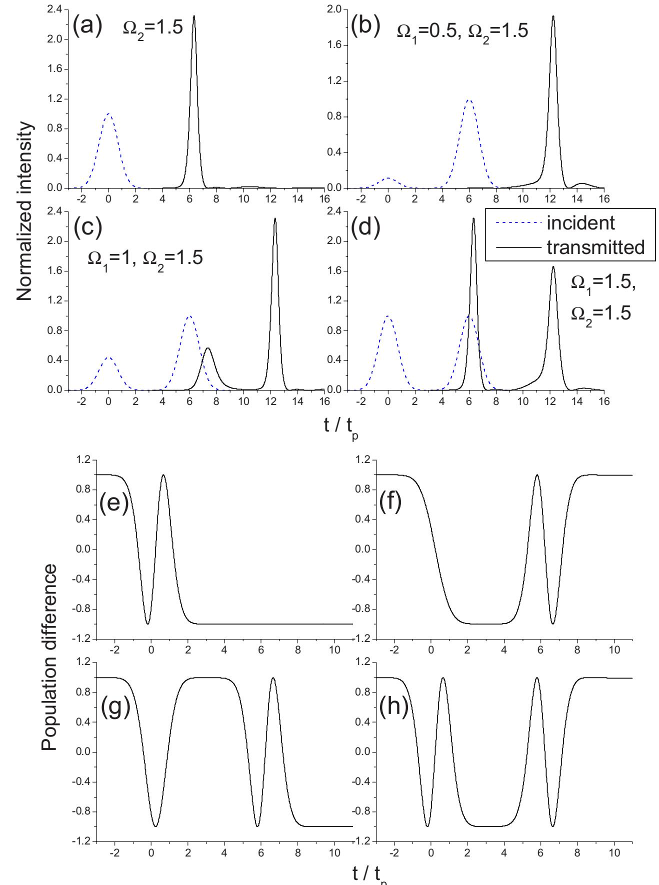

FIG. 14. (Color online) [(a)–(d)] Pulse forms and [(e)–(h)] corresponding population difference dynamics on the entrance of the medium. Intensity of the first pulse [(b), (f)] Ω_1=0.5, [(c), (g)] Ω_1=1, [(d), (h)] Ω_1=1.5, while for the second one Ω_2=1.5. Pictures (a), (e) are for the case of single pulse Ω_2=1.5. Other parameters: L=100λ, b=10.

V. CONTROLLING PULSE INTENSITY BY USING ANOTHER PULSE

A. Copropagating pulses

Let us consider “one-by-one” propagation of two short pulses and interaction between them via the dense resonant medium. As we have seen in Sec. III, the population difference depends on the amplitude of Gaussian pulse in periodic manner at realistic values of parameter b. In this section amplitudes will be expressed in the units of this period $\Delta\Omega_T$. Hence, the behavior of the second pulse with amplitude Ω_2 differs according to amplitude of the first one Ω_1 and, consequently, the state of the medium after it has passed. The results of calculations are shown in Figs. 13 and 14. Obviously, if the first pulse returns the medium to the ground state (Ω_1=1), it practically does not affect the second one. But if after the passage of the first pulse the medium is excited, the second pulse can demonstrate significant increasing [Fig. 13(b)] or decreasing [Figs. 14(b) and 14(d)] of peak intensity. One can treat this effect as controlling of the second pulse intensity by using the first pulse.

The thickness of the dense resonant medium turned out to be an important parameter (see Fig. 15). When the distance traveled by the pulse Ω_2=1.5 is L=50λ or L=100λ, the peak intensity of it appears to be greater in the case of the single pulse than in two-pulse scheme. But at L=150λ (when the single pulse demonstrates attenuation due to diffraction and dispersion) situation becomes reverse. In general, it seems that the first pulse changes the distance of optimal compression of the second one.

In order to make the efficiency of control higher, the PBG structure can be used. For nonlinear layers d_1, more effective compression is obtained only when Ω_1=0.5 [Fig. 16(a)]. However, when both layers d_1 and d_2 are nonlinear, Fig. 16(b) demonstrates increasing in peak intensities for all values of Ω_1. For example, for Ω_1=1.5 it reaches approximately twofold growth in comparison with the single pulse case. The reason for this effect is that photonic crystal provides intense energy exchange between the first and second pulses due to reflections on the layer’s boundaries. The side effect is the difficulty of pulse separation on the output of the system.

B. Counterpropagating pulses

Another scheme of controlling pulse intensity is connected with utilizing of counterpropagating pulse. The ad-

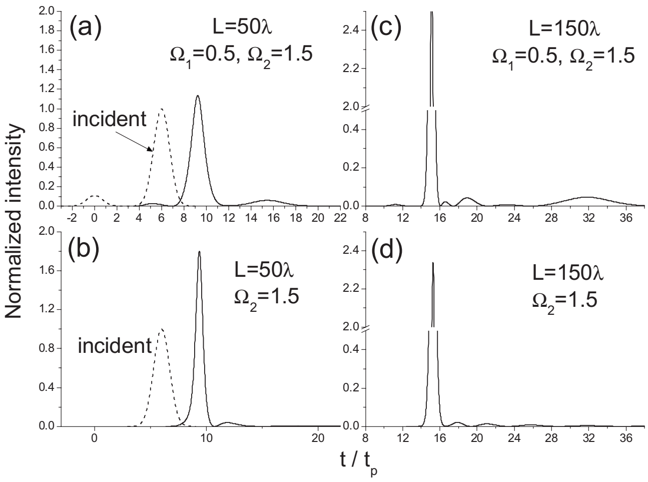

FIG. 15. Pulse forms at different distances in medium. Intensities of the pulses $\Omega_1=0.5$, $\Omega_2=1.5$. Pictures (b), (d) are for the case of single pulse $\Omega_2=1.5$. Parameter $b=10$.

vantage of this scheme is the convenience of separation of pulses as they propagate in opposite directions. The calculation results for the pulse Ω_2, which is controlled with the counterpropagating one Ω_1, are shown in Fig. 17. It is seen that the change in the intensity of the incident pulse Ω_1 leads to the change in the intensity of the transmitted pulse Ω_2, in particular, to its decreasing in comparison with single pulse case. Since the change in the length of optimal compression occurs in this scheme as well, one can obtain an increase in the intensity of $\Omega_2=1.5$ pulse on the distance of about 200λ when $\Omega_1=1$.

Figure 18 shows that the interaction between pulses in the nonlinear photonic crystal is negligible, in contrast to the case of copropagating pulses. It seems to be the result of weak coupling of the pulses in such a system, as they propagate almost independently. This is the great disadvantage in the view of controlling possibilities, but it can be used for simultaneous work with two pulses moving in opposite directions.

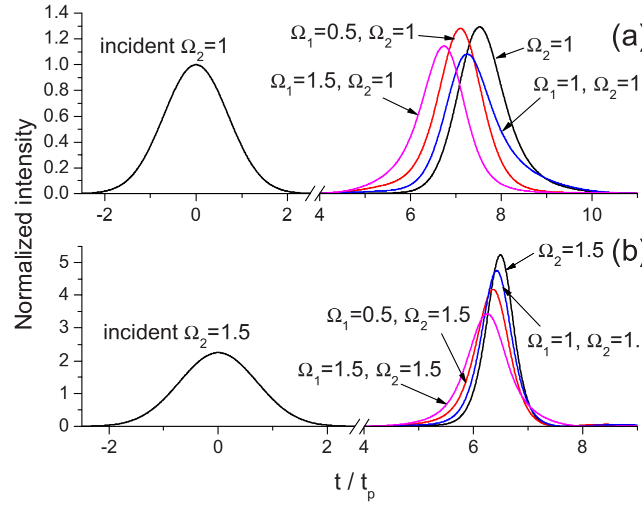

FIG. 17. (Color online) The forms of transmitted pulse Ω_2 controlled with a counter-propagating pulse Ω_1. Intensity of the second pulse is [(a), (c)] $\Omega_2=1$, [(b), (d)] $\Omega_2=1.5$; Ω_1 is variable. Other parameters: $L=100\lambda$, $b=10$.

VI. CONCLUSION

The consideration of intensive radiation interaction with the dense resonant medium in the case of coherent pulse regime allows us to conclude that the influence of near dipole-dipole interactions can be neglected at realistic parameters of the medium, in contrast to stationary case. At the same time, one can observe pulse compression (and splitting) which has certain optimal distance due to the processes of

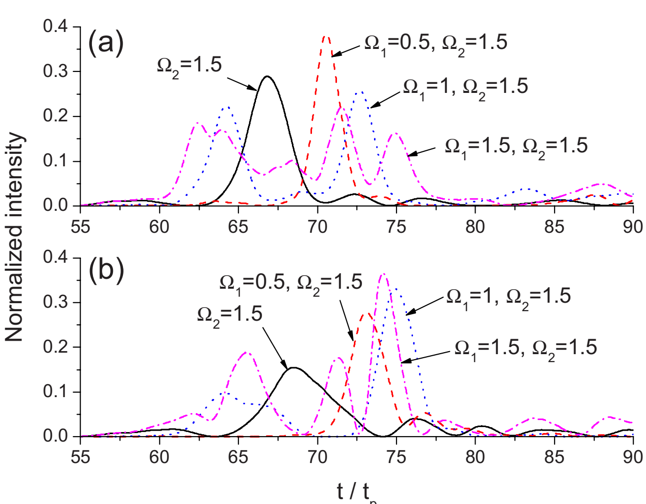

FIG. 16. (Color online) The forms of transmitted pulses after interaction with the photonic crystal (number of periods 250) with (a) nonlinear layers d_1, (b) both nonlinear layers. Intensity of the second pulse is $\Omega_2=1.5$; Ω_1 is variable. Parameters: $n_1=1$, $n_2=3.5$, $d_1=0.4$ μm, $d_2=0.13$ μm, $b=10$.

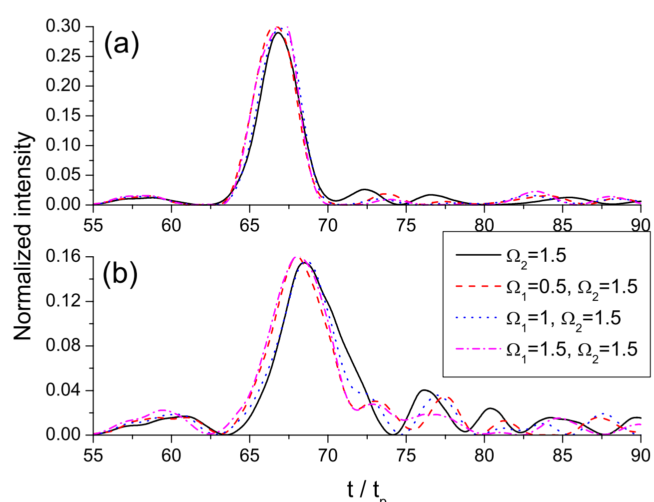

FIG. 18. (Color online) The forms of transmitted pulse Ω_2 after interaction with the photonic crystal (number of periods 250) with (a) nonlinear layers d_1, (b) both nonlinear layers. Intensity $\Omega_2=1.5$; intensity of the counterpropagating pulse Ω_1 is variable. Parameters: $n_1=1$, $n_2=3.5$, $d_1=0.4$ μm, $d_2=0.13$ μm, $b=10$.

diffraction and dispersion. This property of nonlinear compression can be used to compensate dispersive spreading in photonic-band-gap structure containing the resonant medium considered.

It turned out that dense resonant medium allows us to control a pulse with another pulse in schemes of copropagating and counterpropagating pulses. It seems to be useful from the point of view of prospective techniques of optical information storage and processing. Photonic crystal makes the process of controlling more effective, at least in the case of copropagating pulses. For counterpropagating ones, it appears not to be efficient; nevertheless independence of pulse propagation in opposite directions can be used for parallel work with two pulses.

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