SLOWING DOWN THE LIGHT PULSES USING DYNAMIC REFRACTIVE INDEX GRATINGS

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PACS 42.65.Sf

Capabilities to decelerate and accelerate light pulses by means of the self-diffraction from dynamic refractive index gratings with coherent pump and signal waves have been considered. Various implementations of the nonlinear four-wave mixing that ensure a stationary or transient gain of the signal wave intensity and can be used for manipulations with light pulses (two-, three- or four-beam coupling, recording of transmission and reflection dynamic gratings, scalar or vector interaction) have been analyzed. The propagation of light pulses much shorter than the grating build-up time has been demonstrated to occur similarly to that of optical forerunners.

1. Introduction

The fact that light pulses propagate at a velocity different from that of a light wave infinite in time in vacuum, $c = 3\times10^{10}$ cm/s, has already been known for more than a century. A special attention to the propagation of light pulses in media with optical dispersion was drawn at the beginning of the 20-th century by Brillouin's and Sommerfeld' theoretical researches (see, e.g., [1] and original publications since 1913 cited therein). It was shown right then that the group velocity $v_{gr} = \frac{\partial\omega}{\partial k}$, i.e. the velocity of pulse propagation, can be substantially different from the phase one, $v_{ph} = \frac{\omega}{k}$, in a medium with nonzero dispersion. Just at that time, by analogy with the standard refractive index, $n = c\frac{k}{\omega}$, the group index, $n_{gr} = c\frac{\partial k}{\partial\omega}$, was introduced, which could exceed n by many orders of magnitude.

A substantial growth of the optical dispersion arises in a vicinity of resonance transitions. Dispersion can be caused by resonance properties of individual atoms or molecules, or by collective elementary excitations in the solid. Exciton resonances are not an exception to this rule. In particular, the experimental researches of the dispersion in CdS semiconductor crystals carried out by Mykhailo Semenovych Brodyn and his collaborators [2–4] revealed a reduction of the light group velocity to 3×10^6 cm/s, i.e. by four orders of magnitude with respect to the light velocity in vacuum.

Another reason for the appearance of the resonance and, hence, the dispersion can be associated with the phenomenon of the optical diffraction from spatially periodic structures, in which the periods are comparable with the light wavelength. The attention to that fact was paid by Brillouin [1], who proposed a model experiment on studying the propagation of UHF pulses in regular structures consisting of plane-parallel organic-glass plates with air intervals between them [5].

At the end of the 20-th century, a revival of the interest in the light deceleration was observed. It was provoked, first of all, by the application of the quantum-mechanical effect of electromagnetically induced transparency (EIT) [6, 7]. Two coherent waves with precisionally selected frequencies are capable to create a high-contrast narrow dip in the absorption band of a cooled atomic gas. This artificial nonlinear resonance is accompanied by the emergence of a considerable dispersion and a substantial reduction of the light group velocity (down to 17 km/s).

The progress achieved in the realization of extremely long delays for light pulses with the use of EIT gave the scientists an idea of the possibility to use nonlinear Bragg resonances that arise in the interaction of four almost frequency-degenerate waves. The first implementation of this capability taking advantage of the recording of dynamic refractive-index gratings in photorefractive crystals was reported in work [8], where the velocity of light pulse propagation was slowed down to 0.025 cm/s.

In this work, we summarize the results obtained at subsequent stages in the application of photorefractive substances for the manipulation by light pulses. In particular, these are the applications of crystals with two types of mobile charge carriers for slowing down the pulses, practically almost without changing their amplitude [9], and for the pulse deceleration/acceleration switching by varying the pulse length [10]; the application of the backward four-wave mixing for the creation of a two-channel system with different delay characteristics [11]; and the delay implementation in crystals with a local nonlinear response on the basis of the effect of non-stationary energy transfer [12]. Separately, we ex-

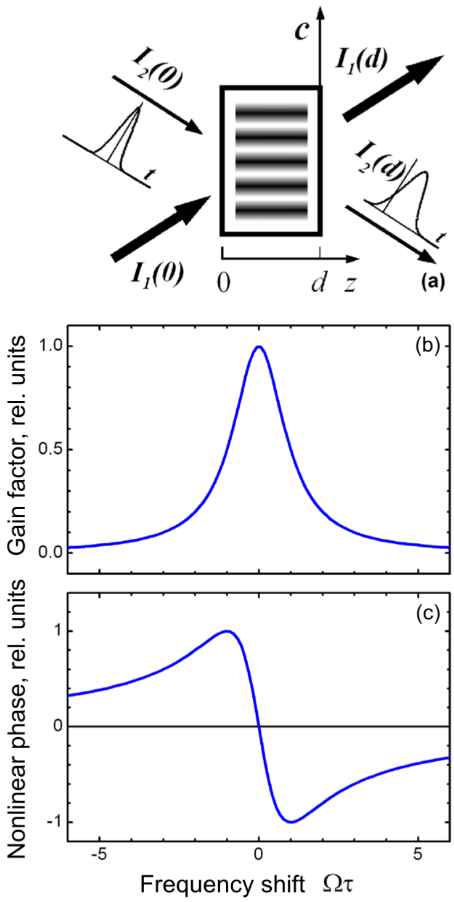

Fig. 1. (a) Schematic sketch of the slowing down of light pulses with a nonlinear coupling of two co-propagating light beams. Dependences of (b) the gain factor for a weak signal wave and (c) the nonlinear increment of the phase at the signal-wave frequency detuning from the pump wave

plain the nature of the related phenomenon consisting in the formation of optical forerunners at the dynamic grating recording [13].

2. Light Deceleration Using $\pi/2$-shifted Dynamic Gratings

When recording a dynamic grating in a crystal with a nonlocal response with the use of a pump beam and a much less intensive signal one, both with identical frequencies, the intensity of the latter can either grow exponentially or fall down, depending on the beam orientation with respect to the crystal polar axis. If the signal wave is confined in time (i.e. it is a light pulse), it is characterized by a definite time spectrum, the components of which differ from those of the pump wave by their frequencies. Such a frequency detuning invokes a

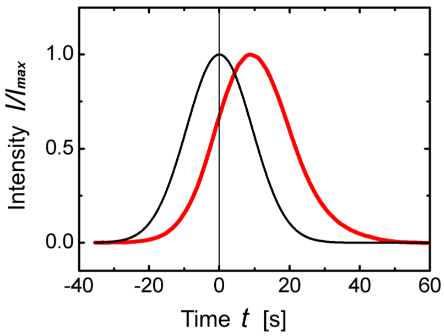

Fig. 2. Time profiles of the input and delayed pulses at recording a $\pi/2$-shifted grating in a $BaTiO_3$:Co crystal

nonlinear increment of the phase of the amplified spectral component, which is proportional to the frequency difference. Therefore, every spectral component propagates in the crystal as if the latter had a specific, slightly changed refractive index.

In Fig. 1, a schematic diagram of the two-beam coupling geometry is depicted (a), and the dependences of the gain factor (b) and the nonlinear phase increment (c) on the frequency detuning of the signal wave with respect to the infinite monochromatic pump one are schematically illustrated.

For a purely nonlocal response, the gain spectrum is Lorentz-like, whereas the spectrum of the effective refractive index in a vicinity of the pump frequency is a linear function of the frequency detuning. As a result, the derivative $\frac{\partial k}{\partial \omega}$ is different from zero, and the dispersion of the group velocity near the gain maximum is low. Hence, we may hope that the delay of light pulses, the duration of which is comparable with the grating relaxation time, will be effective and will take place without a distortion of their time profiles.

Figure 2 illustrates the deceleration of a Gaussian-like pulse 10 s in length in a barium titanate crystal characterized by a relaxation time of about 10 s. For shorter input pulses, the duration of delayed pulses increases to about the relaxation time; for longer ones, their duration at the output coincides with that at the input. The delay changes relatively little at that, being determined by the relaxation time and the coupling strength between the pump and signal waves [7].

An almost constant pulse delay for the growing duration of the input pulse brings about an almost linear reduction of the normalized delay, i.e. the ratio between the delay time $\Delta\tau$ and the duration of input pulse t_0 (Fig. 3).

Should the task be put forward to obtain the pulse delay as long as possible, provided that the pulse temporal profile is preserved, we would have to use input pulses, the duration of which is almost identical to the relaxation time of a dynamic grating.

It should be noted that the deceleration of a pulse is accompanied by the simultaneous growth of its amplitude. For the example exhibited in Fig. 2, the pulse gain factor was 400 (the nonlinear coupling strength $\gamma d = 3$).

The inversion of the polar axis orientation (Fig. 1,a) results in pumping out the intensity and weakening the signal pulse. Simultaneously, the dispersion changes its sign, and the deceleration transforms into the acceleration, i.e. the maximum of the output pulse is observed even before the intensity of the input one has reached the highest value. We emphasize that, among all the versions of nonlinear couplings that were examined in this work, such a complete symmetry of the reaction to the inversion of the polar axis orientation is typical of only the simple two-beam coupling in crystals with a nonlocal response.

3. Light Deceleration Using 0- or π-shifted Dynamic Gratings

In photorefractive crystals with a local response (as well as in a much wider class of nonlinear media with a third-order quasidegenerate nonlinearity in the frequency variable, $\chi^{(3)}$), the shapes of the gain spectra and the nonlinear increment of the phase (they are shown in Figs. 1,b and c, respectively) mutually change one another. For a spectral component, the frequency of which coincides with the pump one, there is no gain in general. This means that there is no energy exchange between waves in the steady state. Moreover, the pulses, whose duration is much longer than the relaxation time, neither accelerate nor decelerate. At the same time, the pulses with the duration $t \le \tau_{di}$ become amplified owing to the so-called non-stationary energy exchange [12].

As was mentioned, the dispersion of $\frac{\partial k}{\partial \omega}$ changes its sign at $\omega = 0$, which testifies that some part of the spectrum forms a delayed pulse, whereas its other part forms an accelerated pulse. Actually, the matter is not so bad, because the intensities of spectral components, which are responsible for the pulse acceleration, get exhausted (the gain factor is always negative for them), whereas the components responsible for deceleration become always amplified. As a result, the amplitude of an accelerated pulse is incomparably smaller than the amplitude of a delayed one. Nevertheless, a distortion of the delayed pulse shape owing to a narrower amplification band in comparison with the case illustrated in Fig. 1,b cannot be avoided; one can try to minimize it only.

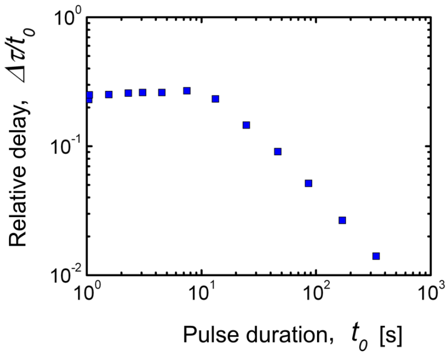

Fig. 3. Dependence of the ratio between the pulse delay and the input pulse duration on the latter quantity

An interesting peculiarity of the media with a local response is the fact that they always slow down light pulses, irrespective of the sign of the nonlinear constant, the sign of an applied external electric field (for photorefractive crystals), and the specimen orientation. On the one hand, this circumstance is associated with a specific property of such media, which consists in that the direction of non-stationary energy exchange is determined only by the beam-intensity ratio. Despite everything, a weaker beam is always amplified, and the amplified beam is always slowed down. On the other hand, it is a reflection of the fact that, if the response is local, the inversion of a specimen orientation does not lead to a change in the spatial shift sign for the refractive index grating. In particular, the zero shift remains to be zero, and the π-shift transforms into the $(-\pi)$-shift; i.e. the physically equivalent situation arises, in which the grating turns out to be shifted by one spatial period exactly $(2\pi - \pi = \pi)$.

We experimentally studied the deceleration of light pulses with the use of dynamic gratings with low spatial frequencies recorded in strontium barium niobate crystals in an external electric field lower than 6 kV/cm. In Fig. 4, an example of the slowing-down of a pulse 6 s in duration at a total light intensity that provides a response time of 3 s is depicted. One can see that the delayed pulse has approximately the same duration as the input one. However, an appreciable asymmetry of the pulse arises, namely, the pulse grows more rapidly than decays. Note that this result concerns a symmetric input pulse with a Gaussian-like distribution. One cannot exclude that such an asymmetric shape for the input pulse could be found that would be preserved at the pulse deceleration with the use of nonlinear media with a local response.

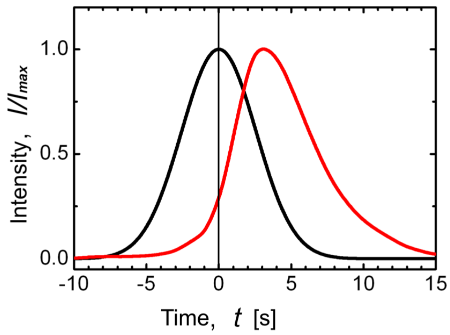

Fig. 4. Time profiles of the input and delayed pulses obtained when using the grating recording in a SBN:Ce crystal SBN:Ce in an external electric field, the strength of which is 40 times as high as the strength of the diffusion field

Figure 5 exhibits the experimentally measured dependences of the pulse delay $\Delta\tau$ and the gain factor $I_{\max}/I_0$ on the input pulse duration. The obtained dependences agree well, both qualitatively and quantitatively, with the model predictions: the pulse amplification has a nonstationary character. In particular, it almost disappears, if the duration of input pulse exceeds the relaxation time of the crystal by an order of magnitude. The solid curves represent the results of calculations according to the theory (see work [14]). It should be emphasized that this calculation contains no fitting parameter: the relaxation time $\tau_{di} = 1$ s and the strength of coupling between the pump and signal waves, $\gamma d = 6.5$, were determined in an independent experiment on two-beam coupling in the same specimen.

4. Deceleration and Acceleration of Light Using Dynamic Gratings Recorded in Crystals with a Nonlocal Nonlinear Response and Two Types of Mobile Charge Carriers

Our inner conviction is that any discussion concerning the priority of amplification or dispersion in the deceleration or acceleration of pulses would remind the elucidation of the problem "Which came first, the chicken or the egg?". Therefore, we searched for such experimental conditions, under which the energy exchange would be minimized, whereas the dispersion would remain high enough. Such conditions do exist in some specimens of photorefractive $Sn_2P_2S_6$, in which radiation excites holes, and the concentration of thermally activated electrons is sufficiently high. When irradiating a specimen with the signal and pump waves, a grating of redistributed holes is formed almost immediately (within a few milliseconds). Free carriers of the opposite sign

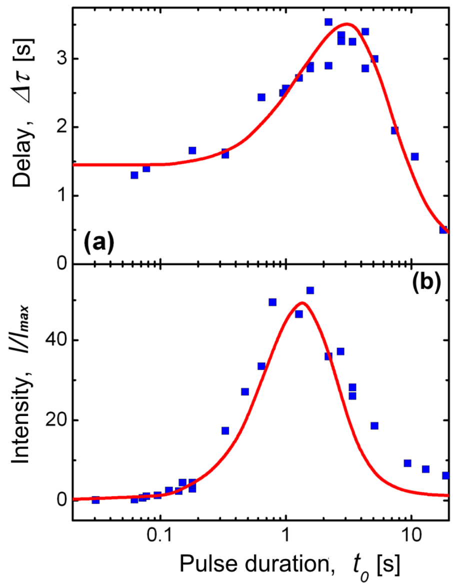

Fig. 5. Dependences of the delay time and the gain factor on the input pulse duration. Parameters: a SBN:Ce crystal in a external electric field of 5.1 kV/cm, the nonlinear coupling strength $\gamma d = 6.5$, and the relaxation time $\tau_{di} = 1$ s

start to move in the electric field of this grating to form a compensating grating within several tens of seconds.

The experimentally measured spectra of the signal wave intensity (the intensity is pumped out just from this wave) and the nonlinear increment of the phase [9] are shown in Fig. 6. The energy exchange almost equals zero at the pump wave frequency, because the space charge gratings formed by carriers with opposite signs are in antiphase and possess approximately identical amplitudes. At the same time, it is in a vicinity of the pump wave frequency, where the highest dispersion of $\frac{\partial k}{\partial \omega}$ takes place owing to a very narrow resonance typical of a slowly compensating grating.

In a nominally pure $Sn_2P_2S_6$ crystal, the spectra of which are shown in Fig. 6, we managed to slow down a 100-s pulse by 6 s, practically without any change of the initial pulse intensity [9, 10]. The specific forms of the gain and the effective refractive index spectra in $Sn_2P_2S_6$ allowed us to observe the transformation of pulse deceleration into pulse acceleration or *vice versa*, which accompanied a gradual increase of the input signal duration, in the same experimental geometry [10]. This phenomenon has a simple qualitative explanation. Let us imagine that the duration of the input pulse is comparable with the lifetime of a rapid grating (it was formed by photoexcited holes within a few milliseconds). Under such conditions, the gain spectrum is characterized

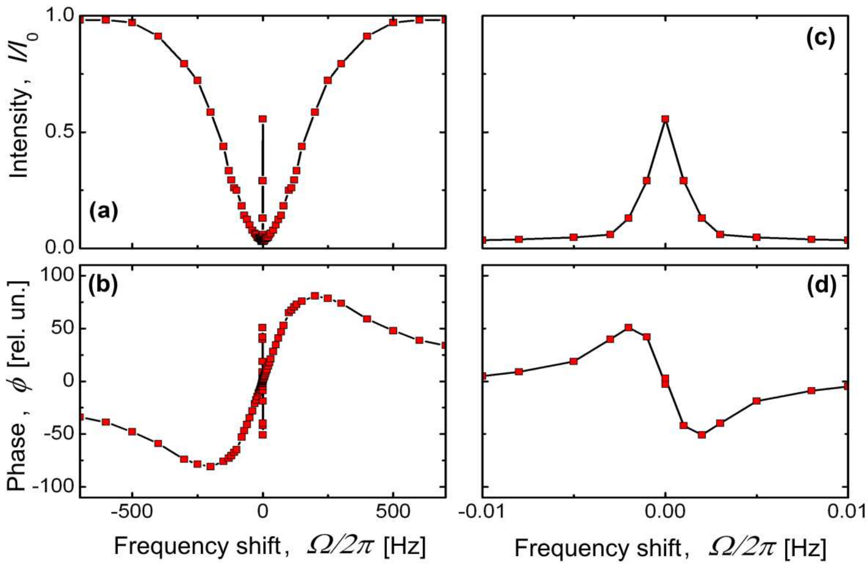

Fig. 6. Experimental spectra of energy exchange (a, c) and nonlinear phase change (b, d) for the two-beam coupling in a $Sn_2P_2S_6$ crystal. The scaled-up dependences (c, d) demonstrate the same dependences in a vicinity of the zero frequency detuning [9]

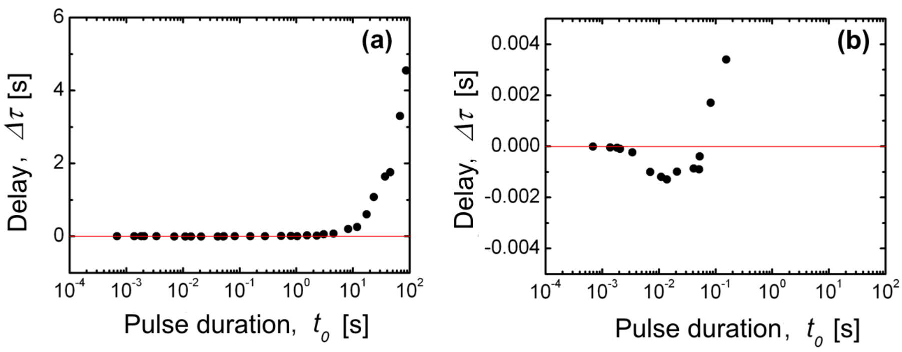

Fig. 7. (a) Dependence of the pulse delay $\Delta\tau$ on its duration t_0 at the two-beam coupling in a $Sn_2P_2S_6$ crystal. (b) The same dependence, but on a larger scale, reveals the sign change for short input pulses

by only a wide Lorentz profile, from which the narrow dip is absent, because the corresponding grating has not been formed yet. The spectrum of the nonlinear increment of the phase is also characterized by a simple wide dispersion profile of $\frac{\partial k}{\partial \omega}$, which corresponds to the short pulse deceleration.

Consider now the medium reaction to a long pulse, the duration of which is comparable with or longer than the lifetime of a slow grating. It is for this case that the stationary spectra with a complicated structure are depicted in Fig. 6. However, we need to consider the circumstance that the long pulse spectrum does not go beyond the range of a narrow dip in the gain spectrum. Therefore, the long pulse feels only the dispersion of $\frac{\partial k}{\partial \omega}$, which has an inverse sign with respect to the dispersion for a short pulse. The change of the dispersion sign gives rise to the transformation of the deceleration mode into the acceleration one.

Note that, in the situation considered, only the acceleration of a long pulse occurs without a change of its intensity. The delay of a short pulse is accompanied by its considerable amplification, because the compensating grating has no time to be formed before the pulse has terminated.

Figure 7 demonstrates the dependence of the pulse delay $\Delta\tau$ on the pulse duration τ, which reveals the change of the effect sign. It is clearly seen (Fig. 7,a) that, starting from $t_0 = 10$ s, the initial pulse slows down more and more until the delay time reaches 5 s at $t_0 = 100$ s. On the larger scale (Fig. 7,b), it becomes evident that the delay sign is negative in the t_0-interval from 2×10^{-3} to

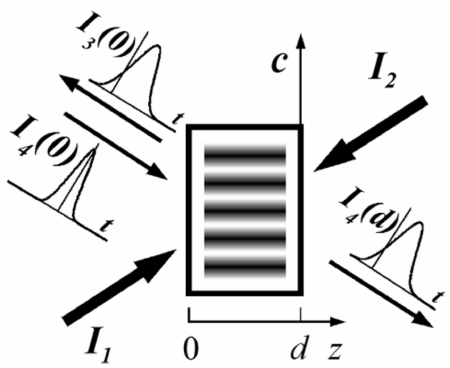

Fig. 8. Schematic representation of the wave coupling in a crystal for pulse deceleration using the BWFWM

5×10^{-2} s, i.e. short pulses are accelerated, rather than decelerated.

5. Slowing Down of Light Pulses Using Backward-Wave Four-Wave Mixing

If a nonlinear medium is irradiated with two counter-propagating pump waves I_1 and I_2, as is shown in Fig. 8, the coupling of signal wave I_4 with pump waves gives rise to the appearance of wave I_3, which propagates backward with respect to the signal one, being phase-conjugate to it. This effect is observed in substances with various media and is referred as the backward-wave four-wave mixing (BWFWM). The figure illustrates how wave I_3 appears as a result of the diffraction of wave I_2 from a "transmission" grating recorded by waves I_1 and I_2. A "reflection" grating recorded by waves I_2 and I_4 can also be used. In the latter case, the wave is formed owing to the diffraction of pump wave I_1.

The dispersion of the photorefractive BWFWM has a more complicated shape than the Lorentz one, the latter being typical of the two-beam mixing [15], but it can also be used to slow down light pulses. Recently, light deceleration has been analyzed theoretically [16] and demonstrated experimentally [17] to take place in the photorefractive BWFWM scheme. The importance of such a demonstration cannot be overestimated, because BWFWM, being based on numerous physical processes, can be implemented in various media, which opens an unconfined spectrum of materials, in which the light deceleration could be realized. In turn, various relaxation times allow one to find substances and processes, which would be optimal for producing decelerated pulses with required characteristics.

An essential difference of the BWFWM from the two-beam one is the different number of output signals. There is only one output signal beam in the two-beam scheme, and two output signals in the BWFWM one, namely, the signal beam that passed through the crystal, $I_4(d)$, and the phase-conjugate beam, $I_3(0)$. These two signals are formed differently and consist of different components. Beam $I_4(d)$ is a result of the interference between the component of input signal $I_4(0)$ that passed through the crystal and the component that is composed of the components of the pump waves that diffract in the same direction. At the same time, beam $I_3(0)$ is only a result of the diffraction of pump waves in the direction backward to that of the input signal. This difference brings about a substantial difference between the delayed pulses $I_4(d)$ and $I_3(0)$ at the excitation by short pulses. In this case, the grating amplitude has enough time to reach rather a small value within the record time interval. Respectively, the diffracted component in the transmitted beam $I_4(d)$ is small, so that the transmitted component of beam $I_4(0)$ dominates. This leads to the observation of the forerunners, the appearance of which will be considered below, when examining the two-beam coupling. As a result, the delay of pulse $I_4(d)$ is insignificant. At the same time, the absence of a transmitted component in the phase-conjugate beam $I_3(0)$ is responsible for its much longer delays. The higher the coupling constant of a crystal, the larger is this difference.

The described differences for the transmitted, $I_4(d)$, and phase-conjugate, $I_3(0)$, pulses were confirmed experimentally [18]. Two pump beams emitted by a continuous Ar^+ laser permanently illuminated a crystal, as is shown in Fig. 8. An electro-optical modulator formed single input pulses with a Gaussian-like profile and the intensity $I_4\left(d=0,t\right) = I_4^0 \exp\left(-t^2/t_0^2\right)$, where t_0 is a pulse half-width at the $1/e$-level. The output pulses experimentally measured for a SBN crystal ($\gamma l = -1.7$, $\tau = 1.4$ s, $t = 0.24$ s) are demonstrated in Fig. 9. The input pulses are denoted by thin curves. It is evident that the phase-conjugate pulse was slowed down much stronger than the transmitted one.

An additional parameter to monitor the BWFWM is the intensity ratio for pump waves, $r = I_1/I_2$. On the one hand, it is natural to work at its optimum value, which depends on the coupling constant, $r_{\mathrm{opt}} = \exp(\gamma d)$. On the other hand, the pump beam I_1 reduces the contrast of interference bands created by beams I_4 and I_2, and, in such a manner, diminishes the effective coupling constant for the transmitted beam. That is why the largest nonlinear changes for the transmitted beam correspond to the ratio $r = I_1/I_2 = 0$ between the intensities of pump beams, i.e. to the two-beam coupling. If the efficiency of BWFWM is not important, we may reduce the r-ratio to obtain larger nonlinear delays. At the same time, it should be noted that, for coupling constants, which are large by absolute value, the optimum ratio $r_{\rm opt}$ is rather small. Therefore, nonlinear delays for the transmitted pulse $I_4(d)$ also approach maximal delays observed at the two-beam coupling. However, delays for a phase-inverted beam of short pulses always remain longer (not shorter) than those for the transmitted beam at any duration of input pulses.

To summarize this section, it should be noted that the manipulation with light pulses is possible in any geometry of the four-wave mixing. Besides the BWFWM scheme, also useful are concurrent ones, in which the signal wave is directed onto the crystal along a conic surface with an aperture angle equal to the angle between two pump waves. Simultaneously with the signal wave amplification, the so-called idle wave, which has a conjugate wave front with respect to the signal, arises and gets amplified. The temporal characteristics of a deceleration for the signal and idle waves are similar to those considered above in the case of the backward-wave mixing.

The majority of photorefractive crystals are birefringent, which allows more complicated schemes of concurrent mixing to be applied in the cases where the pump waves and the signal one belong to different characteristic waves of the crystal by their polarization. The list of possible BWFWM versions and the calculations of corresponding gain factors can be found in work [19]. However, only some of the processes considered in work [19] allow an amplification of the signal and idle waves that would be permanent in time, whereas the others provide only a transitive non-stationary amplification. Nevertheless, all of them can successfully be used to manipulate light pulses in time. The only difference consists in that the non-stationary gain processes cannot be used to slow down pulses, whose duration considerably exceeds the relaxation time of the dynamic grating. An obvious advantage, which the parametric processes of nonlinear coupling between concurrent waves with different polarizations possess, consists in that they provide an ultrahigh gain for the signal wave, with an increment of growth of $100 - 200$ cm^{-1} [20]. We may hope that such an amplification will allow the absolute values of light pulse delay to increase substantially.

Additional possibilities can be provided by using hybrid resonances in nonlinear crystals, where, in addition to the dynamic grating formed by light waves, there already exists a permanent grating of the refractive index or a grating of ferroelectric domains [21]. Advantages of the use of hybrid resonances, e.g., in lithium niobate with a grating of domains, consist in a suppression of the undesirable "optical damage" effect and in an expansion of the interval of angles, at which the signal wave can be directed.

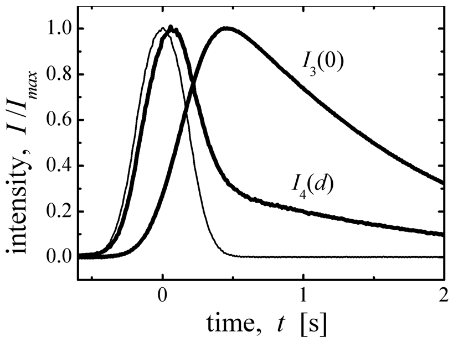

Fig. 9. Time dependences for the intensities of input pulses, $I_4(0)$ (thin curve), transmitted pulses (curve $I_4(d)$), and phase-conjugated pulses (curve $I_3(0)$) for an SBN crystal

6. Optical Forerunners at Dynamic Gratings

Any dispersion cannot arise instantly. Some time is required for a dynamic grating to be recorded, a collective excitation like an exciton to appear, or vibrations of electron shells in atoms to be excited. This time varies from fractions and hundreds of seconds for photorefractive lattices to pico- and femtoseconds for electronic excitations. Essential is the basic possibility to choose light pulses with a so short duration, that certain processes of dispersion formation have no time to run. Such a short pulse propagates in a medium, without feeling its dispersion, the formation of which needs longer times. The attention to this circumstance was paid by Brillouin and Sommerfeld, who coined short pulses that do not feel the medium dispersion as optical forerunners [1].

We detected forerunners, which are associated with the formation of photorefractive gratings, and used them as examples to study the general properties of any optical forerunners predicted by Brillouin and Sommerfeld [13]. It was demonstrated that the input pulse with a duration much shorter than the relaxation time, $t_0 \ll \tau_{di}$, creates a double-humped pulse, the first maximum of which is practically not delayed in time (the forerunner), whereas the second maximum is characterized by a delay of about τ_{di}. As the duration of the input pulse grows, only the intensity of the delayed part in the output pulse grows, and the forerunner ceases to be appreciable in due course. Figure 10 exhibits the experimentally measured (a) and calculated (b) time dependences for the output pulse, provided the two-beam coupling

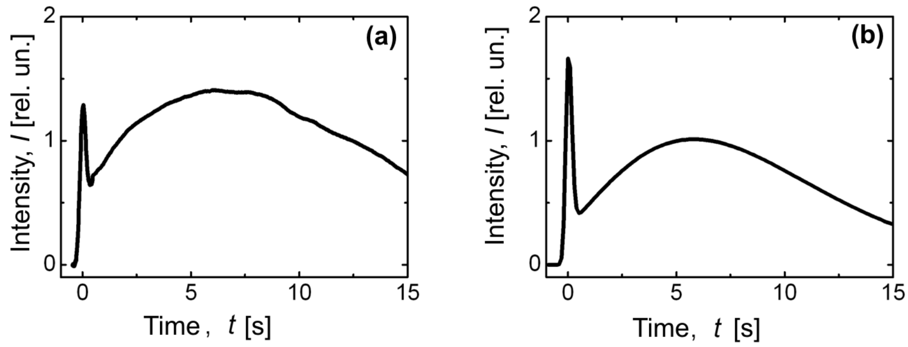

Fig. 10. Experimental (a) and calculated (b) time profiles of a pulse at the output of a $BaTiO_3$ crystal at the two-beam coupling

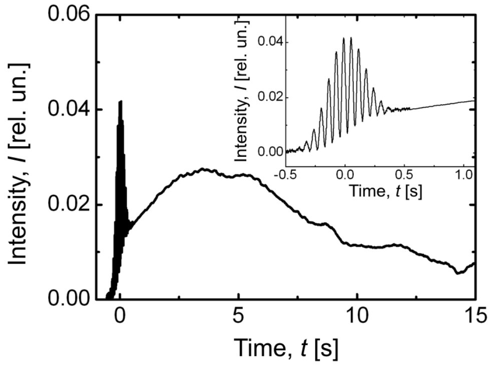

Fig. 11. Variation of the output pulse intensity in time at the two-beam coupling in a $BaTiO_3$ crystal. The intensity of the input signal with a Gaussian-like shape was additionally modulated with a frequency of 100 s^{-1}. The inset demonstrates the time structure of a forerunner on the larger scale

in a $BaTiO_3$ crystal. The calculation parameters are $t_0 \approx 0.5$ s, the coupling strength $\gamma d = 3.7$, and the relaxation time $\tau_{di} \approx 3$ s.

The photorefractive grating is formed by means of a redistribution of charge carriers and the emergence of a static electric field. The crystal symmetry can change in the field; for instance, a uniaxial birefringent crystal can transform into a biaxial one. By definition, the forerunner propagating in a crystal, where the space charge grating has had no time to be formed, does not feel the induced symmetry variation. At the same time, the delayed pulse propagates already in the crystal with a changed polarization of characteristic waves. This was confirmed by us experimentally in work [13].

The Bragg resonance from a photorefractive grating is very narrow; in this specific experiment, its half-width amounted to 0.35 s^{-1}. If the signal wave includes some components of the time spectrum that are located beyond the Bragg resonance, those components will be filtered off from the delayed pulse. However, they will survive in the forerunner, because the latter is insensible to the grating dispersion. Figure 11 illustrates the result of the experiment, which confirms this statement; in particular, the output pulse can be clearly resolved into a forerunner modulated in time with a frequency of 100 s^{-1} and a smooth delayed pulse.

7. Conclusions

Frequency quasidegenerate four-wave mixing interactions based on the recording of dynamic refractive index gratings are an effective tool for the manipulation with light pulses (their deceleration or acceleration). In this work, such capabilities have been mainly illustrated using our own researches as an example. An interested reader can find the additional information on this issue in a chapter of the collective monography devoted to photorefractive crystals [22].

For today, a possibility to reduce the group velocity of light down to hundredths of centimeters per second and to delay pulses by tens of seconds has already been confirmed experimentally. Till now, the confined frequency band for a signal to be decelerated and a relatively small value for the delay normalized by the duration of the input pulse (≤ 1) have been remaining an essential restriction to this technique.

We are grateful to all colleagues from the scientific centers at Novosibirsk, Bonn, and Dijon for the cooperation at various stages of this research, and to our partners from the Uzhgorod National University for supplying us with $Sn_2P_2S_6$ specimens.

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Received 08.09.11.
Translated from Ukrainian by O.I. Voitenko

УПОВІЛЬНЕННЯ ІМПУЛЬСІВ СВІТЛА ІЗ ЗАСТОСУВАННЯМ ДИНАМІЧНИХ ҐРАТОК ПОКАЗНИКА ЗАЛОМЛЕННЯ

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Р е з ю м е

Розглянуто можливості уповільнення та прискорення імпульсів світла шляхом запису динамічних ґраток показника заломлення із когерентною по відношенню до сигнальної хвилею накачки. Проаналізовано різні варіанти реалізації нелінійної чотирихвильової взаємодії, які забезпечують стаціонарне або перехідне підсилення сигнальної хвилі і можуть бути використані для маніпулювання світловими імпульсами (двопучкова, трипучкова, чотирипучкова взаємодії; запис ґраток на пропускання або на відбиття; скалярні або векторні взаємодії). Показано, що поширення імпульсів світла із довжиною значно меншою за характерний час формування ґратки показника заломлення відбувається так само, як поширення оптичних провісників.