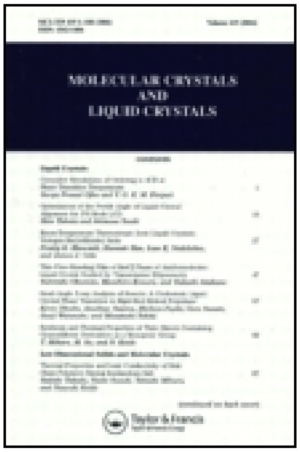

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I. V. Goosev [a] , V. A. Krivoschekov [a] & B. Ya. Zel'dovich [a]
[a] Nonlinear Optics Laboratory, Technical University, Chelyabinsk, USSR
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STEADY STATE STIMULATED SCATTERING BY THE GRATING NONLINEARITY IN NLC

I.V.GOOSEV, V.A.KRIVOSCHEKOV, B.YA.ZEL'DOVICH
Nonlinear Optics Laboratory, Technical University,
Chelyabinsk, USSR

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Abstract The forward stimulated O $\rightarrow$ E scattering with the replication of wave front in nematic liquid crystal 5CB was observed for λ=0.63μm radiation with very low intensity, 0.03W. The scattering was due to short- period (3μm) gratings of director and therefore the frequency shift was 30Hz, buildup time was 0.04 seconds.

The high third-order nonlinearity in nematic liquid crystal (NLC) is connected with the reorientation of its director by the laser radiation. Moreover the nature of this reorientation can be conventionally attributed to two types: quasihomogeneous and grating.

In this report we discuss the second part. Consider the simultaneous co-propogation of ordinary and extraordinary waves which are mutually coherent and are propagating perpendicular to the director **n** in the planar NLC cell. Then the polarization of the summary field **E** in NLC will be changed periodically in the medium:

$$\mathbf{E} = \mathbf{e}_x E_e \exp(ik_e z) + \mathbf{e}_y E_O \exp(ik_O z) \tag{1}$$

in that situation the director distribution is

$$\mathbf{n}(z,t) \simeq \mathbf{e}_x + \theta(z,t)\mathbf{e}_y \tag{2}$$

Where θ is the angle between **n** and $\mathbf{e}_y$. In such a scheme the dielectric susceptibility tensor asquires the nondiagonal addition which was periodical for z and leads to rescattering of O- and E-waves into each other.

That results in the amplification a wave with one polarization at the expense of the wave with another one by that mechanism. The weak amplified signal may be produced either by external source or by spontaneous scattering of the pump wave.

The equation for the NLC-director in linearised approximation has the form

$$\eta\frac{\partial\theta}{\partial t} + K_{22}\frac{\partial^2\theta}{\partial z^2} = \frac{\varepsilon_a}{16\pi}\left(E_O E_e e^{iqz-i\Omega t} + E_e^* E_O e^{+i\Omega t-iqz}\right) \quad (3)$$

Where $|q|=(\omega/c)(n_e-n_O)$ is the wave vector of director grating which is written in the volume of NLC, $\varepsilon_a=n_e^2-n_O^2$ is dielectric anisotropy of NLC on the optical frequency ω, $\Omega=\omega_O-\omega_e$ is the frequency shift between pump and scattering wave, K_{22} is the Frank constant, η is the orientational viscosity.

In the steady state

$$\theta(z,t) = \frac{\varepsilon_a}{16\pi K_{22}q^2}\left[\frac{E_O^* E_e e^{iqz-i\Omega t}}{1+i\Omega\Gamma^{-1}} + \text{c.c.}\right] \quad (4)$$

where $\Gamma=K_{22}q^2/\eta$ is the relaxation constant of the grating. Therefore the shortened equations for the signal on the e-polarization have the form [1]:

$$\frac{dE_e}{dz} = \left(\frac{g}{2} + i\delta k\right)E; \quad g + 2i\delta k = G|E|^2 \cdot 2\,\frac{\Omega+i\Gamma}{\Omega^2+\Gamma^2} \quad (5)$$

Here the gain coefficient g (cm^{-1}, by intensity), G is the gain constant at the point $\Omega=\Gamma$, δk is correction to the wave of signal, which describes the mutual focusing. G has the dimension cm/W if the power density of the wave $|E|^2$ had the dimension W/cm^2.

Till now only nonstationary stimulated scattering (SS) was realized with the use of pulsed ruby laser radiation [2]. The steady-state SS was realized in the geometry of small angle between the director and pump wave vector (the gomeotropic orientation of director) and for rather hight power of cw argon laser radiation [3]. That defined the comparatively large director's deformation period.

In our report there is the experimental realization of steady-state SS of ordinary wave into extraordinary one due to grating nonlinearity in NLC.

The linearly polarized radiation from He-Ne laser (λ=0.63 μm) with power up to 50mW was directed to 1mm thick planar cell with 5CB crystal. That pump corresponded to ordinary wave for such cell. We have abserved the wide-angle linear thermodynamically equalibrium scattering from O- to E-wave (~15 ÷ 20%). Beside that, we have observed the nonlinear stimulated scattering with the threshold pump power $P_o \geq$ 5mW. The diameter (FWe^{-2}M) of the focal waist of laser beam in NLC-cell was $2\sqrt{2}a_o$ ~ 10μm, its length Δz(FWHM) = $2(\omega n_o/c)a_o^2$ ~ 700μm was completely inside the cell.

The hights nonlinear conversion coefficient R from O- to E-wave was ~50%. The frequency shift between pump and scattered wave was measured by two methods.

In the first one the polarizer was placed at the exit of the cell at the 45^o angle to the scattered wave polarization. That permited to observe the interference between the pump and scattered wave. These interference beats were registed with the help of an oscilloscope. The beats period depended on the frequency shift Ω. The Fourier-transform and correlation function of those oscillograms were calculated. The analysis of those data allowed to estimate the frequency shift $\Omega/2\pi$ ~25Hz.

In the second method the spectral profile of the weak signal gain was registed. With the help of the sawtooth generator and the piezomirror the frequency of the signal to be amplified was shifted from -60 to +60Hz.

The maximum of the signal wave gain was at the Stokes frequency shift $\Omega = \omega_s - \omega_p = -24 \pm 5$Hz. The theoretical estimation of the optimum signal frequency shift is $\Omega = \Gamma =$

$= K_{22}q^2/\eta = 2\pi(27Hz)$ for 5CB (for $t = 20^0C$). Here $K_{22}=5\cdot10^{-7}$dyne, $\eta \sim 1.2$Poise, $q \sim 2\cdot10^4cm^{-1}$ (the grating period $\Lambda = 2\pi/q \sim 3\mu m$). It can be seen that the results of both methods are in a good agreement with the theory.

The single-pass gain of signal intensity is determined by the factor $\exp(\int g_{eff}dz)$. One should also take into account the transverse overlapping of Gaussian beams of the pump and Stokes wave. Finally we get

$$\int g_{eff}dz = \frac{8\pi^2}{\lambda_0 c}GP_0 \qquad (6)$$

where P_0(W) is pump power; c and λ_0 are speed of light and wavelength in vacuum.

When the polarization of illuminating wave was 45^0, i.e. had the same frequency and intensity at the input of the NLC-cell, the mutual focusing (cross-focusing) was observed.

In conclusion, we have observed the SS at very short length, $\leq$ 1mm, with unusually (for LC) large frequency shift, $\Omega/2\pi \sim 25$Hz and spatial locality, $1/q \sim 0.5\mu m$ with very low threshold power, $\sim 5\cdot10^{-3}$W.

This will allow to amplify wide angle signals, $\Delta\theta \sim n_a/n \sim 0.12$ radians, with relatively quick responce.

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