Generation of increasing light signals during the parametrical process on photo-integrated anisotropy

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The observation results of the generation of increasing light signals during the parametrical process on photo-integrated anisotropy are presented. The sufficiently big growth of the intensity of small signals of the basic frequency infra-red radiation with time (photo-stimulated amplification of light) has been detected in experiments with the influence on amorphous optical material by the weak probe radiation of the basic frequency in presence simultaneously the strong radiation of the second harmonic. Various modes of the amplification of light signals were investigated on preliminary created photo-integrated space-periodical anisotropy with different initial amplitudes. The results of the detailed studies of the generation of increasing light signals on photo-integrated anisotropy have been presented with demonstration of the investigated properties of the observed parametrical process in dependence on intensities of the pumping radiation, on polarization of the light signals, on the phase shifts and on the spatial distributions. Mechanisms of the occurrence of the parametrical generation process on photo-integrated anisotropy with the existence of the non-steady regimes of signal amplification are also discussed. The presented investigations may be interesting for the researchers in a spheres of photonics and micro-optoelectronics. The work was carried out as the part of tasks of the Russian State Project FWGW-2021-0012.

For nonlinear process of parametrical down frequency conversion (or parametric amplification of low light signals) the photo-integrated by volumetric all-optical poling susceptibility tensor of $\chi^{(2)}_{int}$ grating:

$$\chi^{(2)}_{ijk}(\Omega;2\Omega,-\Omega) = (\chi_1^{(3)}\boldsymbol{E}_k\delta_{ij} + \chi_2^{(3)}\boldsymbol{E}_j\delta_{ik} + \chi_3^{(3)}\boldsymbol{E}_i\delta_{kj}),$$

$$\chi_1^{(3)} = 2\pi\chi^{(3)}_{iijj}(\Omega;2\Omega,-\Omega), \quad \chi_2^{(3)} = 2\pi\chi^{(3)}_{ijij}(\Omega;2\Omega,-\Omega), \quad \chi_3^{(3)} = 2\pi\chi^{(3)}_{ijji}(\Omega;2\Omega,-\Omega).$$

So, maximal nonlinear conversion of light observed for radiation polarized along the direction of the induced electric field $\boldsymbol{E}$. But there are the other non-zero components.

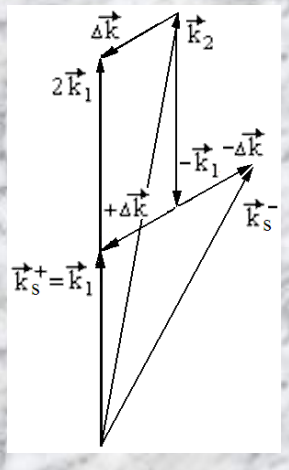

Fig 1. Phase synchronism on photo-induced grating $\chi^{(2)}_{int}$ for nonlinear process of degenerate parametrical down frequency conversion with amplification of low light signals of basic frequency.
The low signal wave with the wave vector $\boldsymbol{k}_s = \boldsymbol{k}_1$ and the big power pumping wave with the vector $\boldsymbol{k}_p = \boldsymbol{k}_2$ interact in medium with photo-integrated $\chi^{(2)}_{int}$ grating with vector $\Delta\boldsymbol{k} = 2\boldsymbol{k}_1 - \boldsymbol{k}_2$ by condition of phase synchronization $\boldsymbol{k}_s = \boldsymbol{k}_2 - \boldsymbol{k}_1 \pm \Delta\boldsymbol{k}$. As the $\boldsymbol{k}_s^+$ coincide with incident basic light beam $\boldsymbol{k}_1$, the spatial phase synchronism for inducing $\chi^{(2)}_{int}$ grating and signal wave with basic frequency is carried out automatically and there is a case of the nonlinear degenerate parametrical amplification of low signals.

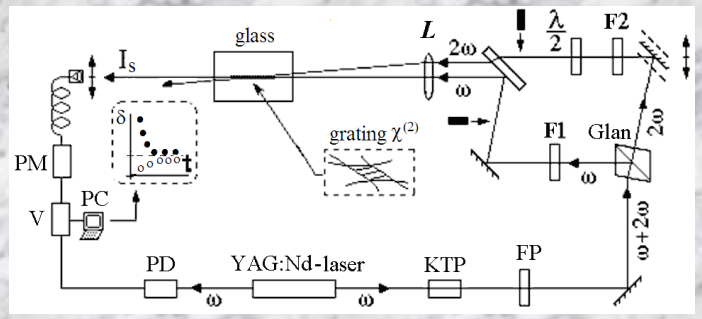

Fig. 2. Experimental set-up. After making grating $\chi^{(2)}$ the intensity of the beam ω was reduced in 1000 times in presence of the powerful pumping radiation 2ω and the dynamics of the amplification in time for small light signals with frequency ω was studied.

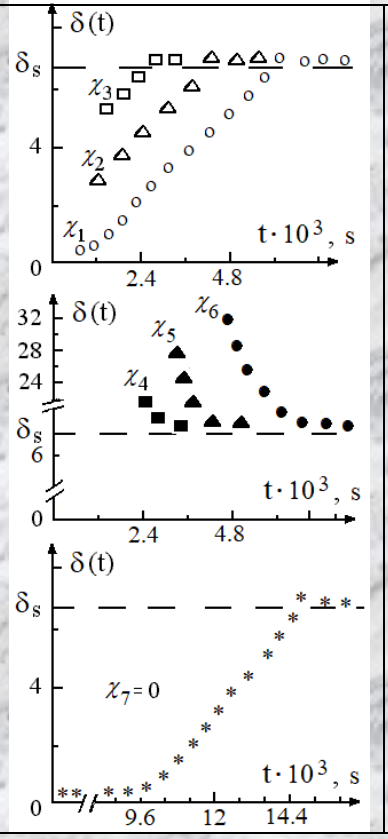

Fig. 3. Dependences on time for light amplify-cation coefficient $\delta(t) = I_s/I_{in}$ in parametrical down frequency conversion process on photo-integrated space-periodical $\chi^{(2)}$-gratings.
So, for small initial $\chi^{(2)}$-gratings (χ_1, χ_2, χ_3) coefficient δ(t) grows in time and reaches some steady-state level δ_s=const. For big initial $\chi^{(2)}$-gratings (χ_4, χ_5, χ_6) coefficient δ(t) falls in time and reaches also steady-state level δ_s. The amplification was observed even in absence of initial $\chi^{(2)}$-grating (χ_7=0), but in this case the time of the reaching of level δ_s was very large. So, observed process of parametrical amplification in photo-integrated space-periodical anisotropy in glass has some non-stationary period. Such behavior may be connected with existence of interdependence. So, amplification of light signal leads to the increase of the amplitude of $\chi^{(2)}$-grating and the increase of the $\chi^{(2)}$ leads to the increase of the parametrical amplification as the positive feedback in system.
Steady-state amplification coefficient δ_s for light with perpendicular to the pumping polarization was in 5 times less than in case when the probe and pumping light waves had parallel polarizations. Results correspond with components of tensor $\chi^{(2)}$ that non-equal to zero. Dependence steady-state coefficient δ_s from the phase shift between signal and pumping was sinusoidal also as in theory.

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