BROADENING OF SPECTRUM IN SELF-FOCUSING OF LIGHT IN CRYSTALS

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When light is self-focused in a liquid, an anomalous broadening of the frequency spectrum is observed in the self-focusing channel, reaching values on the order of several hundred Angstrom units in the case of picosecond pulses [1 - 3]. In the study of self-focusing of the radiation of a neodymium laser (λ = 1.06 μ) in glasses we have observed an emission-spectrum broadening that overlapped the wave band (0.45 - 1.06) μ.

The experimental setup is illustrated in Fig. 1. A neodymium laser with a four-lamp illuminator (IFP-5000 lamps) operated on the fundamental transverse mode when the resonator was Q-switched with a saturable filter. By suitable adjustment of the generator elements and by introducing additional selecting plates it was possible to ensure either emission of a single-frequency monopulse, or partial synchronization of the modes (Fig. 2a). In the latter case, the emission spectrum had a width on the order of 5 - 10 Å.

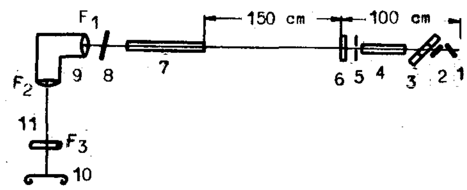

Fig. 1. Block diagram of experimental setup: 1 - total-reflection mirror, 2 - plane-parallel polarizing plates, 3 - nonlinear filter, 4 - active element (340 × 20) in a four-ellipse illuminator, 5 - circular diaphragm (2.5 mm diameter), 6 - plane-parallel output plate, 7 - glass rod, 8 - SZS-15 filter; 9 - ISP-51 spectrograph (F_1 = 304 mm, F_2 = 800 mm), 10 - photographic film, 11 - cylindrical lens, F_3 = 150 mm.

Self-focusing of the collimated laser beam in silicate-glass samples was observed only in the partial-synchronization regime. In the monopulse regime, no changes were observed in the structure of the beam even when an additional amplifier was used. Self-focusing occurred simultaneously in the active laser element, leading to irregularity in the mirror field. The investigated glass samples were therefore placed 150 cm away from the generator, where the transverse structure of the beam was close to Gaussian.

Self-focusing was investigated in neodymium glass (LGS-228) and in glass of LK type with a transparency region ranging from near ultraviolet to 1.4 μ[1]. The occurrence of a self-focusing channel in the investigated glass sample was revealed by the appearance on its output face of a bright point in the generator beam. We observed in this case neither the filamentary damage to the glass in the self-focusing channel nor the lateral channel glow characteristic of such damage. In LGS-228 glass samples 118 to 405 mm long, the self-focusing occurred in the energy interval 0.4 - 0.15 J.

To register the broadening of the spectrum, the output end face of the glass rod was projected through an ISP-51 spectrograph (Fig. 1) on a photographic film. Figure 3 shows the pictures of the spatial-spectral distributions of the field on the end, recorded on different films. For comparison, the figure shows also a mercury-lamp spectrum. The bright axial line on Fig. 3a or 3e represents

[1]The exact brand of the second glass was unknown.

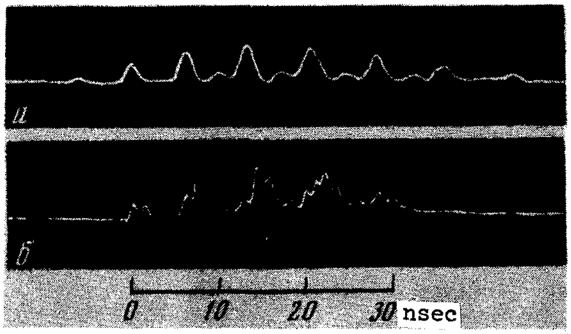

Fig. 2. Oscillograms of emission pulses: a) at the generator output, b) at the output from the investigated samples past the SZS-22 filter.

the spectrum of the end of a self-focusing filament. This spectrum covers a wide range of wavelengths and overlaps the entire visible region. The filament is surrounded by a halo that disappears only for the LGS-228 glass in the absorption band[2]. The halo decreases with decreasing rod length and disappears practically completely at rod lengths corresponding to the instant of vanishing of the point on the end face. With further shortening of the rod, the effect of the spectral broadening disappears together with the self-focusing point on the end face.

The polarization and the time variation of the radiation, measured in the range 0.35 - 0.6 μ (SZS-22 filter), turned out to be the same as in the generator beam, except that the individual beams were more strongly cut up (Fig. 2b).

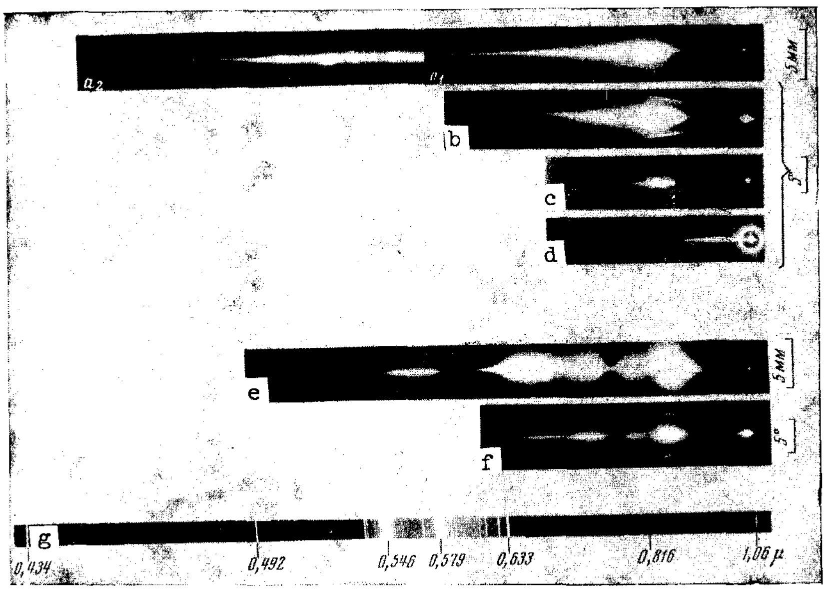

Fig. 3. Spatial and spectral distributions of the field on the end of the glass rod.

Figure 3 shows also the spectral pictures of the far field of the radiation after self-focusing. They were obtained with the aid of a cylindrical lens 11 (Fig. 1) mounted in such a way that the plane of the initial image of the end coincided with the focal plane of the entire apparatus in the focusing cross section of this lens. With the exception of the absorption bands, the entire observed radiation spectral interval has a sharp maximum surrounded by a weak background with a divergence of several degrees. On the long-wave end of the spectrum, the background is sharply outlined by two intense lines coming from the vicinity of the point $\lambda = 1.06$ μ. The distance between the lines depends on the type of glass. For the LGS-228 glass in the range $\lambda < 0.83$ μ, the boundary of the background is separated from the rays and approaches the axial line

[2]) The change of the width of the halo as a function of the wavelength is connected to a considerable degree with the non-uniform sensitivity of the photographic film and the strong increase of the dispersion of the ISP-51 instrument in the short-wave section of the spectrum.

monotonically with decreasing wavelength; for LK glass, there is no such boundary. Figure 3c shows a diagram of the radiation emerging from the LK glass, obtained with a large spectral resolution (a vertical slit 0.4 mm wide was placed in the plane of the end face of the rod). In the vicinity of the axial line ($\theta = 0$) one can see the characteristic "whiskers" described by the parabolic law $\Delta\lambda \sim \theta^2$.

A similar self-focusing picture was observed in sapphire. There is no doubt that both the self-focusing and the transformation of the spectrum are connected with a low-inertia mechanism of electronic nonlinearity. As shown by estimates, the observed broadenings of the spectrum are attainable in principle in a medium with such a nonlinearity as a result of phase automodulation [4, 5] of the collapsing ultrashort pulses[3]. The distinguishing features of the near and far fields after self-focusing may be due to aberrations of the nonlinear nonstationary lens produced in the self-focusing channel. At the same time, one cannot fail to call attention to the fact that kinematically the far field is more similar to the picture of anomalous (superluminar) Doppler effect [6] which can be observed when oscillators with different natural frequencies ω_i pass through a medium with normal dispersion $n''_\lambda < 0$[4], and in this case the limiting rays on the long-wave end of the spectrum would have to be interpreted as Cerenkov radiation of a static source[5].

We propose to refine the foregoing considerations concerning the nature of the observed effect of superbroadening of the spectrum in the course of our subsequent research.

The authors are grateful to A.V. Gaponov and A.A. Andronov for useful discussions.

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[3] Favoring the indicated mechanism are also preliminary experiments performed with the second harmonic of a neodymium laser, which have shown that the superbroadening of the spectrum occurs on both sides of the fundamental frequency.

[4] Such a dispersion is possessed by glasses and by sapphire in the range under consideration.

[5] The possible occurrence of Cerenkov and transition radiation from bunches with averaged polarization were first pointed out by G.A. Askar'yan [7]. Self focusing of monopulses (with formation of traveling focal points [8]) or of ultrashort pulses (with formation of regions of intense nonlinear polarization accompanying the motion of the pulse) uncover apparently ways of investigating this effect. (As kindly reported to us by V.V. Korobkin, in experiments with self-focusing in carbon disulfide the reflected pulses of the Stokes component are predominantly on the output internal face of the cell. It is possible that such an effect is due to the appearance of transition radiation.)

In the article by N.G. Bondarenko, I.V. Eremin, and V.I. Talanov, Vol. 12, No. 3, page 86, line 20 from the top, read "individual spikes" and not "individual beams." On the same page, the caption of Fig. 3 should read: Spectral scan of the radiation at the output of the glass rod: a - d) LK glass, e and f) LGS-228 glass; g) spectrum of mercury lamp with additional lines $\lambda = 0.63\ \mu$ and $\lambda = 1.06\ \mu$; a, e) spectrograms of the image of the end face of the rod; b, c, d, f) spectrograms of the far field after self-excitation. Films used: a, b, c, e, f - I-810, a_2 - KN-3, d - I-1070; spectrum d was obtained without filter 8 of Fig. 1.