CANCELLATION OF PHASE DISTORTIONS IN AN AMPLIFYING MEDIUM WITH A "BRILLOUIN MIRROR"

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Optical quantum amplifiers are now extensively used to increase the power of lasers. An increase of the amplifier radiation power, however, is accompanied as a rule by a deterioration of its directivity, due to static or dynamic (produced under the influence of the pump) inhomogeneities of the refractive index in the amplifying medium [1]. We report here a method of obtaining high directivity of the amplified radiation when the optical quality of the amplifier is low.

It was recently established that the wave front of light reflected as a result of stimulated Mandel'shtam-Brillouin scattering (SMBS) can reproduce the front of the exciting radiation [2]. By using this effect, we succeeded in cancelling out the phase distortions in the amplifier, thus improving appreciably the divergence of the amplified radiation.

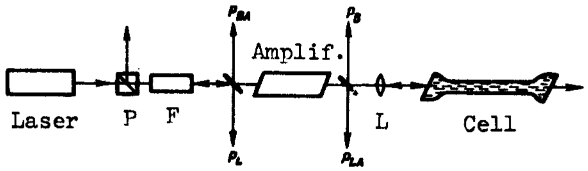

Fig. 1. Experimental setup: P - polarizer (Glan prism), F - Faraday cell that rotates the plane of polarization of the light through 45°; amplifier - ruby crystal 24 cm long and 12 mm in diameter, with end faces cut at 4° angle; L - lens of focal length 25 cm; the cell is filled with carbon disulfice and has a diameter 3 mm, a length 1 mm and is located 70 cm away from the amplifier.

The experimental setup is shown schematically in Fig. 1. A beam of light from a ruby laser, with a divergence close to the diffraction value, passes through an amplifier whose optical quality is poor, and then enters a cell with carbon disulfide, where the SMBS process develops. The cell "acts" as a mirror that changes the wave front of the laser radiation into its complex conjugate. The wave front of the reflected light should remain at any point the complex conjugate of the laser radiation front[1]. Consequently, the reflected light should have, after passing through the amplifier, the same front as the laser radiation entering the amplifier.

In our setup, the backward-moving light was spatially separated from the laser light with an optical insulator consisting of a Faraday cell and a polarizer [3]. The amplifier was a ruby crystal with a weak-signal gain ranging from 5 to 19. The laser light (P_L) entering the amplifier had a divergence ~0.13 mrad at half-height, at a beam diameter 6 mm, spectrum width <20 MHz, and maximum power ~0.1 MW. The time dependence of the power is shown in Fig. 2. The same oscillogram shows (in a different scale) a pulse of reflected and then amplified light (P_{BA}). It is somewhat shorter than the laser pulse, probably owing to the nonlinear dependence of the power of the reflected light on the power of the exciting radiation [4].

The laser radiation passing through the amplifier was focused by lens L ahead of the cell with the carbon disulfide and entered the latter in the form of a divergent beam. The cell was made of glass. Since the refractive index of glass is smaller than that of CS_2, total internal reflection takes place at their interface, and the light passes through the cell as in a waveguide with reflecting walls. To prevent lasing, the ends of the cell are expanded and blackened, and its windows are inclined 60°.

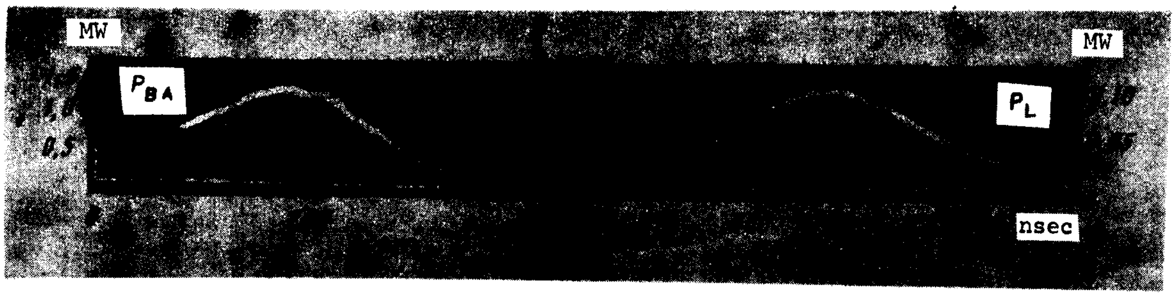

Fig. 2. Oscillogram of laser light and reflected light when the gain in the ruby is equal to 10.

[1] This statement, of course, does not hold if the gain is not constant over the amplifier cross section, i.e., if there are amplitude distortions of the front in the amplifier.

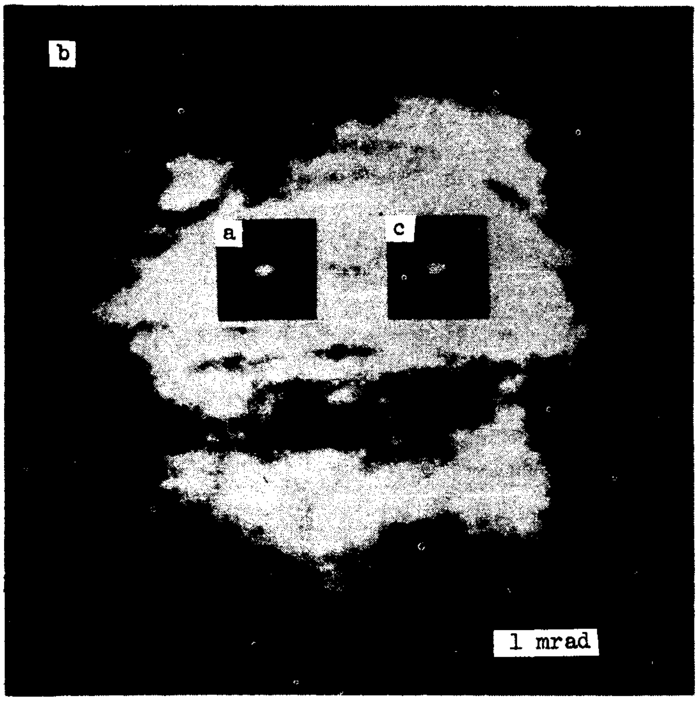

Fig. 3. Photographs of the distribution in the far zone: a - laser radiation, b - amplified laser radiation, c - reflection of light passing through the amplifier.

Figure 3a shows the distribution, in the far zone, of the non-amplified laser radiation. Figure 3b shows, in the same scale, a photograph of the far zone of the amplified radiation (P_{LA}). Comparison of Figs. 3a and 3b shows that the amplifier distorts strongly the front of the light passing through it, increasing the divergence from 0.13 to ~2.5 mrad.

An appreciable fraction (~60% in energy) of the radiation entering the CS_2 is reflected backwards as a result of the SMBS[2)]. The distribution of the reflected light (P_B) in the far zone duplicates in its details Fig. 3b.

After the reflected light passes through the amplifier, its divergence is noticeably decreased and becomes equal to ~0.15 mrad. As seen from Fig. 3c, the far-zone distribution of the reflected and then amplified light is quite close to the distribution of the non-amplified laser radiation. This effect is observed both when the amplifier operates linearly and when it is saturated.

We have thus established that by using SMBS we can cancel out the distortions in the amplifying medium and obtain an amplified light beam with a divergence close to the diffraction value. This method is not selective and can be used in laser systems operating at various wavelengths. The short time of SMBS establishment (~10^{-9} - 10^{-8} sec) makes it possible to compensate for dynamic inhomogeneities. For example, it is possible to compensate for such inhomogeneities in liquid amplifying media.

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2) In CS_2, the SMBS gain is 0.04 cm/MW and the width of the gain contour is 75 MHz [5].

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