DECREASE OF LASER BEAM DIVERGENCE BY PASSAGE THROUGH AN OPTICAL AMPLIFIER

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The passage of a pulse from a single-mode ruby laser through a traveling-wave amplifier is investigated. It is shown that at high incident-flux intensity the divergence of the radiation may decrease.

In this paper we investigate the passage of a radiation pulse from a single-mode Q-switched ruby laser through a traveling-wave amplifier. We establish that the spatial structure of the field of the amplified wave can be appreciably altered, depending on a number of factors; in particular, under certain conditions the beam may even become narrower.

We used in the amplifier ruby crystals 120 mm long and 10 mm in diameter, with Brewster end faces, excited with a straight flash lamp. The master generator was a single-mode ruby laser [1] with a diffraction divergence 1.3×10^{-3} rad (the divergence was readily decreased to 2.5×10^{-5} rad by using a telescope with aperture 5 cm). The generator radiation energy was 0.02 J at a beam diameter 0.8 mm (for the fundamental oscillation mode).

The radiation spot did not remain round after amplification (in the near zone), and acquired the form of an ellipse with an axis ratio dependent on the magnitude of the pumping. The minor axis of the ellipse was in the plane of incidence of the ray on the end face of the ruby. The amplitude distribution over any diameter of the ellipse was nearly Gaussian. It can be shown that the elliptic form of the spot in the near zone is due to the geometry of the pump system and of the active sample.

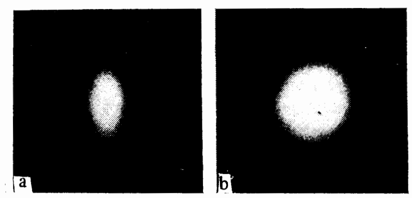

FIG. 1

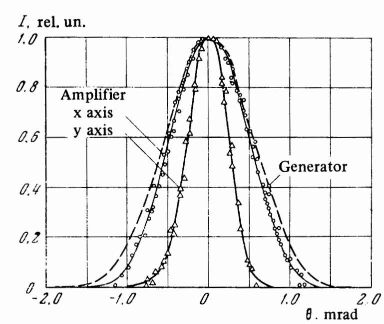

FIG. 2

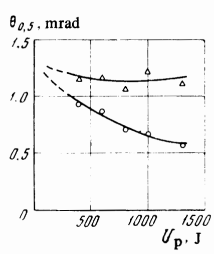

FIG. 3

The structure of the field of the amplified wave in the far zone also has the form of an ellipse, as seen in Fig. 1a (for comparison, Fig. 1b shows the corresponding structure of the field of the master generator). The angular distribution of the intensity (I) in the direction of the principal axis of the ellipse is shown in Fig. 2, which is obtained by photometry of several photographs corresponding to different flashes (the pump energy was 1000 J, and the gain was approximately equal to three). We see that the divergence of the radiation in the direction of the plane of incidence (y axis) is much smaller than the divergence of the laser beam, and this effect is more strongly pronounced at high pump levels (Fig. 3; upper curve— x axis, lower curve—y axis). In the perpendicular direction (x axis), the angle width of the beam remains practically unchanged.

The narrowing of the directivity pattern in the amplification process can be attributed to saturation of the gain at high field intensities. Indeed, the average energy density in the beam at the input of the amplifier reached 4 J/cm^2, and in the central region it was much larger. At such energy densities, the amplification becomes an essentially nonlinear process, and therefore the gain for the central regions of the beam is smaller than for the peripheral ones. As a result, the dimensions of the spot in the near zone increase, and this leads to a narrowing of the directivity pattern.

It should be noted that the elliptical radiation spot in the far zone is oriented in the same manner as the ellipse in the near zone, and not in a perpendicular direction as expected. Such an effect can be attributed to thermal bending of the end surfaces of the crystal, which in the case of a rod with Brewster cuts becomes more strongly pronounced in a direction perpendicular to the incidence plane. Therefore the distribution of the phase at the exit face of the crystal along this direction turns out to be highly inhomogeneous, thus increasing the beam divergence. Indeed, the divergence turns out to be approximately three times larger than the diffraction divergence calculated from the dimensions of the spot in the near zone. At the same time, the divergence in the incidence plane is close to the diffraction value. The influence of the ''lens'' effect of the amplifier crystal on the radiation divergence in this plane is small, and leads to a slight (~10%) narrowing of the beam (to clarify the influence of this effect, we investigated the case when the optical axes of the generator and amplifier crystals lie in perpendicular planes, and consequently the influence of the gain is eliminated).

The pulse duration following the amplification was approximately the same as at the input (~8 nsec), and a forward shift of the maximum of the amplified pulse (by approximately 2 nsec) was observed; this shift was first investigated in[2].

[1] A. L. Mikaélyan, V. G. Savel'ev, and Yu. G. Turkov, ZhETF Pis. red. 6, 675 (1967) [JETP Lett. 6, 161 (1967)]; Voprosy radioelektroniki, seria obshchetekhnicheskaya (Problems of Radioelectronics, General Technical Series) 18, 3 (1967).

[2] N. G. Basov, R. V. Ambartsumyan, V. S. Zuev, P. G. Kryukov, and V. S. Letokhov, Dokl. Akad. Nauk. SSSR 165, 58 (1965) [Sov. Phys.-Dokl. 10, 1039 (1966)].

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187