DYNAMICS OF THE FIELD AND GENERATION FREQUENCY IN A GIANT PULSE OF A LASER WITH PASSIVE SHUTTER

V. V. Korobkin, A. M. Leontovich, M. N. Popova, and M. Ya. Shchelev
P. N. Lebedev Physics Institute, USSR Academy of Sciences
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The dynamics of the field and the generation frequency have been thoroughly investigated experimentally for a laser in the free mode (cf. e.g. [1]), but no such investigation were made for a laser in the giant-pulse regime.

We have investigated the dynamics of the field and the generation frequencies in the giant pulse of a ruby laser with passive shutter. The passive shutter used was a cell with a solution of cryptocyanine in ethanol. The initial transmission of the cell was 15% for the λ = 6943 Å wavelength. The cell was placed between the flat mirror with reflection coefficient 98% and a ruby crystal 120 mm long and 11.5 mm in diameter. The second mirror, located 50 cm from the first, had a reflection coefficient of 30%. The laser action, initiated on the end face and on the 30% mirror, bleached the cryptocyanine solution and a giant pulse developed. The pulse energy was 0.5 - 0.8 J and the duration was 12 - 15 nsec at the half-power level.

The time sweep of the field pattern and the time spectra of the generations were with the aid of an electron-optical converter (EOC) operating in the slit-scanning mode and providing a resolution of 0.5 nsec.

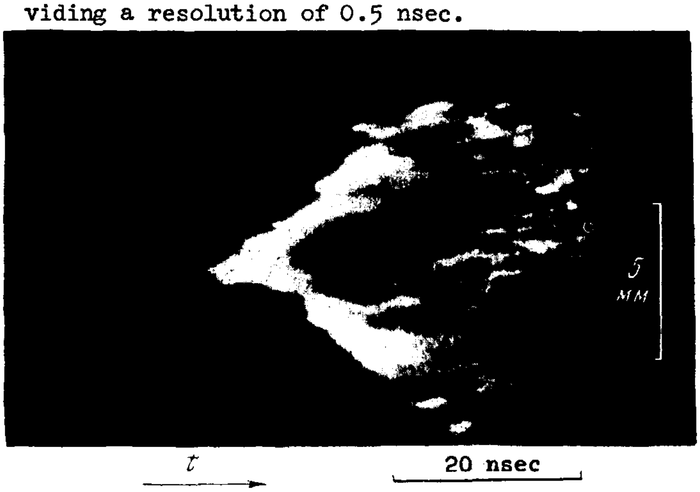

Fig. 1. Scanning of generation field on the end of the crystal.

Figure 1 shows a photograph of the scanned generation field on the end of the crystal. We see that the generation begins in a central region of about 1 mm, and then spreads over the entire end surface within ~15 nsec, the total duration of the pulse being 30 nsec at the zero-power level. The most intense generation regions shift in this case to the outer edges of the end face. The initial generation period, when only the small central region of the crystal is in operation, ranges from 1 to 8 nsec on different photographs. This difference in duration is due to the fact that the region in which the generation began was not always aimed on the EOC slit.

We see from Fig. 1 that individual small regions, spaced 0.1 - 1 mm apart, are in operation on the end surface. In each such region we observe a pulse of duration 1.8 - 4 nsec. The subdivision of the generation region into individual sections can be attributed to the operation of higher-order modes and to the inhomogeneity of the crystal.

Figure 2 shows the development of the generation field in the far zone. At the start of the generation the divergence is 1.2 - 1.5' and increases subsequently to 20'.

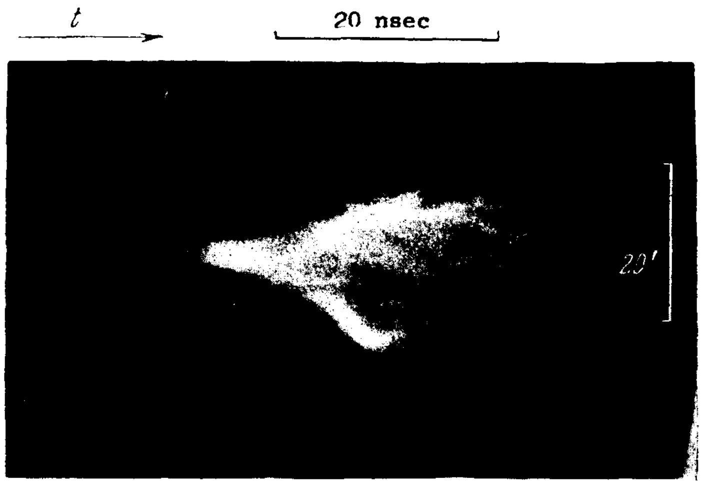

Fig. 2. Scanning of generation field in the far zone (directional distribution of the radiation).

We note that such a variation of the field must be taken into account in calculations of the power of the field at the focus of a lens. For example, if the pulse energy is 1 J and the field distribution is the same as in Fig. 2, an estimate of the average power density at the focus of a lense of focal length 5 cm yields a value of 2×10^{11} W/cm^2. If no account is taken of the time variation of the generation field we should obtain for the same 1 J energy a figure of 3×10^{10} W/cm^2, i.e., lower by almost one order of magnitude.

The time sweep of the generation spectrum of the giant pulse obtained with the aid of a Fabry-Perot interferometer with 150 mm spacing between mirrors is shown in Fig. 3.

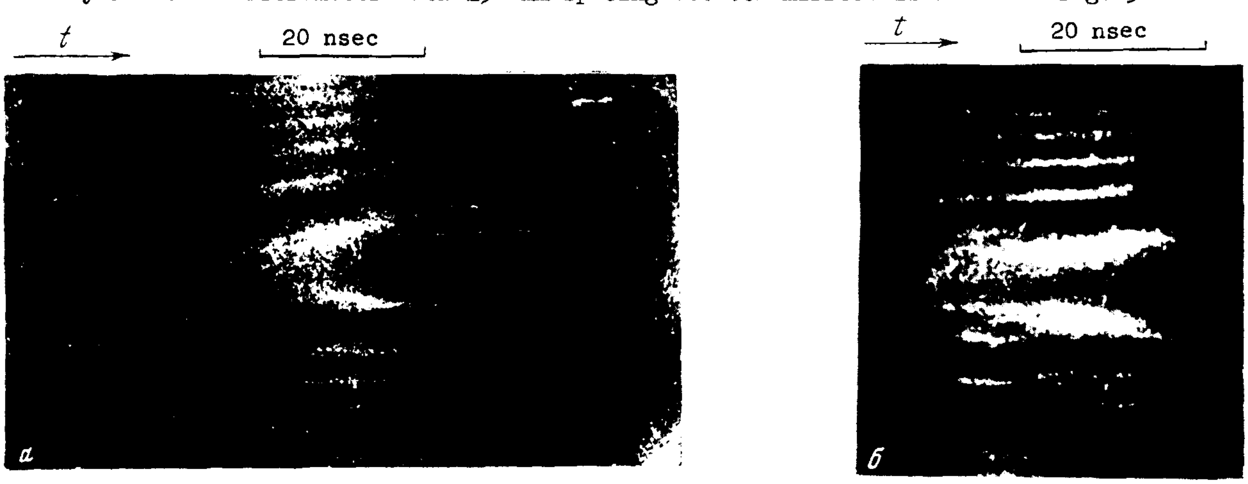

Fig. 3. Scanning of generation spectrum: a - generation at one frequency, b - generation at two frequencies.

The individual bands correspond to different Fabry-Perot orders. We see from Fig. 3 that the frequency shifts toward the violet side during the course of generation. This shift amounts to 0.012 - 0.015 cm^{-1} during the generation time. The line width at each instant is ~ 0.01 cm^{-1}. Sometimes one more frequency corresponding to the neighboring axial mode was generated during some time (Fig. 3b).

The observed change in the generation field of the giant pulse of a laser with passive shutter is in good qualitative agreement with the results of the theoretical paper of Suchkov and Letokhov [2], which, to be sure, pertains to the case of instantaneous Q-switching and not to the case of a passive shutter. There are no calculations as yet for passive shutters.

The change in the generation field is evidence of the change in the transverse of the mode index from low values of the order of 1 to a value of the order of 50. This was estimated by comparing the divergence and the dimension on the end face, in the same manner as used by Korobkin et al. [1]. If we assume that the axial index does not change, then the increase in frequency, calculated with the formulas given in [3], should be $\Delta V/c \approx 0.3$ cm^{-1}, which is larger by one order of magnitude than our measured value 0.02 cm^{-1}. The possible change in the optical length of the resonator, due to the decrease in the refractive index of the cryptocyanine in alcohol when heated by the laser light, should also shift the frequency to the violet side and cannot offset the shift due to the change in the order of the mode. The cause of the frequency shift we measured is still unclear.

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[3] G. D. Boyd and J. P. Gordon, Bell Syst. Techn. J. 40, 489 (1961).