SELF-FOCUSING OF RUBY LASER RADIATION IN CdS CRYSTALS

I. V. BARANOVSKIĬ, A. A. BORSHCH, M. S. BRODIN, and A. M. KAMUZ

Institute of Physics, Ukrainian Academy of Sciences

Submitted 31 August, 1970

Zh. Eksp. Teor. Fiz. 60, 1593–1596 (May, 1971)

Propagation of the radiation from a single-mode ruby laser in a CdS crystal is observed directly. It is found that with increase of intensity the laser beam becomes narrower in the crystal. The narrowing is observed at certain values of the intensity. The critical power for self-focusing of radiation from a single-mode ruby laser in a CdS crystal is determined.

THE positive change in the dispersion of a CdS crystal we observed[1] upon subjecting it to intense radiation from a ruby laser, as well as the specific peculiarities in the photoconductivity of CdS by two-photon excitation by a ruby laser[2], suggest that this radiation is self-focused in this crystal. We have now verified this directly in an investigation of the geometry of propagation of ruby laser light in a CdS crystal at T = 290°K.

A single-mode Q-switched ruby laser was used in our work, single-moding being achieved by the scheme proposed in[3]. Single-mode operation was monitored by observing the structure of the field in the far zone, as well as by interferograms obtained with a Type IT-51-30 Fabry-Perot interferometer. The total power of the laser was about 10 MW for a pulse length of 15×10^{-9} sec.

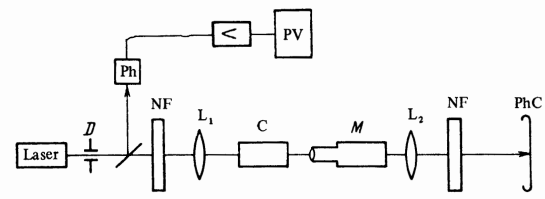

FIG. 1. Experimental setup.

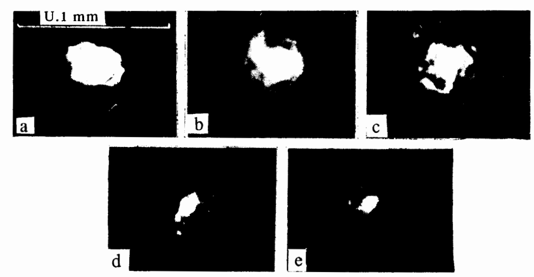

FIG. 2. Image of the cross section of a ruby laser beam in a crystal of CdS (at the lens focus): a–P = 150 kW; b–P = 300 kW; c–P = 700 kW; d–P = 1.6 MW; e–P = 2.1 MW.

The experimental setup is shown in Fig. 1. Radiation of the single-mode ruby laser with Gaussian distribution of intensity over its end-face and attenuated by the neutral filter NF to the desired power is focused by the short-focus lens L_1 (F = 5 cm) onto the rear surface or in the volume of the investigated crystal C. The image of the focal section of the lens or of planes close to it is transferred to the camera PhC by the microscope-lens system L_2 and photographed. A neutral filter after the crystal is employed to obtain normal densities on the film.

To measure the beam power, part of it is deflected and directed to a calibrated measuring system consisting of a photocell, extender, amplifier, and pulse voltmeter.

Using this system, we investigated the distribution over the face of the laser beam intensity in the crystal in front of the geometrical focus, at the focus, and beyond the focus of the lens for different intensities.

In all sections investigated in the interval from 2.5 to 0.5 mm in front of the focus the beam became narrower as the power was increased. In addition, at powers greater than 300 kW, together with the compression of the central portion of the beam, an additional background appears, which spreads out to the periphery with increasing laser beam intensity at the entrance to the crystal.

The change in cross section of the beam in the crystal in the focal plane is shown in Fig. 2. In Fig. 2a it is seen that the additional background around the focal spot already appears at powers of 150 kw. At powers of the order of 300 kW this background acquires a ring structure, with the rings spreading out to the periphery with increasing laser beam intensity. The uniform central portion of the focal spot, on the other hand, narrows with increasing intensity of the incident beam, and at a power of P = 2 MW its diameter is 7 μm. Note that with further increase of laser intensity (above 2 MW) the focal spot ceases to be homogeneous and divides into several regions of smaller diameter.

This break-up of the laser beam is particularly well marked in sections located at a distance of 1 to 2 mm beyond the lens focus. The appearance in these sections of inhomogeneities in the beam (separate spots) occurs at powers as low as 200 kW. As the laser intensity is increased the inhomogeneities narrow and move closer to the beam axis. Here also is seen the additional background in the peripheral portion, which spreads out from the beam axis as the power entering the crystal is increased.

Since CdS belongs to the hexagonal system, it is birefringent. However, in our experiments the general behavior of the ordinary and extraordinary rays is the same, although we did not compare the threshold characteristics. Hence, in all the experiments we describe we reduced the intensity of the extraordinary ray to a minimum by rotating the crystal and worked only with the ordinary ray.

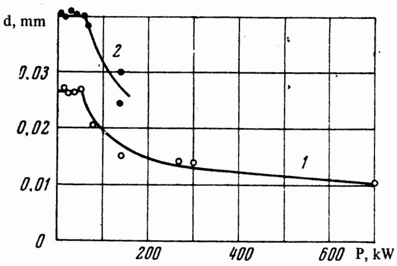

FIG. 3. Dependence of the diameter of a ruby laser beam in a CdS crystal on intensity. Curve 1—at the lens focus; curve 2—1.5 mm beyond the focus.

Thus, in the cross sections we investigated both at the lens focus and at distances of up to 2 mm on both sides of it we find a narrowing of the laser beam in CdS crystal as the intensity is increased. This narrowing can only be attributed to self-focusing. Evidence for this is also furnished by the threshold character of this phenomenon. This is seen in Fig. 3, which illustrates the dependence on intensity of the diameter of the laser beam in the CdS crystal at the lens focus and 1.5 mm beyond it. The diameter of the beam remains practically unchanged to an incident intensity of 60 kW, after which it sharply decreases. Consequently, the value of the critical power for self-focusing is P_{cr} = 60 kW.[1)] From this we can determine the coefficient of nonlinear change of the refractive index using the formula in[4]: $P_{cr} = (1.22\lambda)^2 c/256 n_2$. We obtain $n_2 = 1.4 \times 10^{-2}$ cgs esu.

The additional background referred to above may be due to some kind of stimulated scattering out of the region of the self-focused beam. To check this assumption we made a spectral investigation of the radiation coming out of the crystal. With an ISP-51 spectrograph and UF-89 camera the radiation coming out of the crystal was analyzed for the presence of stimulated Raman scattering. The results obtained showed that the observed background does not lead to the appearance of additional lines in the spectrum of the laser radiation and thus is not due to stimulated Raman scattering.

The presence of stimulated Brillouin scattering was checked with an IT-51-30 interferometer. However, we were unable to register any radiation the frequency of which differed from the frequency of the incident radiation. The resolution of the system was $\delta\nu = 0.008$ cm^{-1}.

We can say therefore that there is no stimulated scattering with a frequency change greater than 0.008 cm^{-1}. This means that the observed background that spreads out to the periphery must have the same frequency as the radiation incident on the crystal.

The simultaneous presence of a narrowing and divergence of the beam may be due to competing processes. We can in fact suppose that in principle two mechanisms act in succession at the time of the laser pulse; the mechanisms change the dispersion, but in opposite directions. In particular, this can be the longwave shift of the line of a free exciton under the action of ruby laser radiation observed earlier[1], which leads to a positive change in dispersion, and the partial saturation of the absorption of bound excitons, which leads to a negative change in n. However, to check this assumption it is necessary to investigate the temporal characteristics of this phenomenon.

Thus, direct observations of the geometry of propagation of ruby laser radiation in a crystal of CdS has disclosed the presence in it of self focusing of the laser radiation and has made it possible to determine the threshold for its appearance more accurately.

1)Our earlier estimates of this quantity yielded P_{cr} = 180 kW. [2]

[1] M. S. Brodin and A. M. Kamuz, Ukr. Fiz. Zh. **14**, 517 (1969).

[2] A. A. Borshch and M. S. Brodin, Zh. Eksp. Teor. Fiz. **58**, 26 (1970) [Sov. Phys.-JETP **31**, 15 (1970)].

[3] A. L. Mikaélyan, Yu. G. Turkov, and V. G. Savel'ev, ZhETF Pis. Red. 6, 675 (1967) [JETP Lett. 6, 161 (1967)].

[4] S. A. Akhmanov, A. P. Sukhorukov, and P. V. Khokhlov, Usp. Fiz. Nauk **93**, 19 (1967) [Sov. Phys.-Uspekhi 10, 609 (1968)].

Translated by L. M. Matarrese
174