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THERMAL SELF-ACTION OF AN ANNULAR LASER BEAM IN A SOOT-PARTICLE AEROSOL

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Propagation of an intense laser beam in a medium containing solid particles can be accompanied by thermal distortions [1, 2]. Experimental and theoretical investigations were carried out [3, 4] on the dynamics of thermal distortions of a cw Gaussian beam (λ=10.6 μm) in an aerosol of soot particles. For practical applications, interest has been attached to beams with an intensity dip in the axial region, or annular beams (see, e.g., [5-7]). We report below the results of experiments on thermal self-action of an annular cw beam (λ=10.6 μm) in a sooty aerosol under conditions of autoconvective motion of the medium.

The experiments were performed with the setup shown schematically in Fig. 1. The acting CO_2-laser beam 1, operating in a multimode regime at a power 25 W and beam divergence ~ 10', was reflected from mirrors 2 and 3 and entered a smoke chamber 4 (length 2 m, cross section 0.4 × 0.4 m). At a distance 0.2 m from the exit opening of the chamber was located a photoresistor 10 with a diaphragmed entry 9. The diaphragm diameter was 0.8 mm. In front of the photoresistor was placed a modulator operating at 1000 Hz. The signal from the photoresistor was fed to an amplifier 11 and next to a detector 12 and to an N327 automatic plotter 13. The optical depth of the aerosol in the chamber was monitored by a beam-splitting salt plate 5, a focusing salt lens 6 and a power meter 7. Two measurement runs were made. In the first the mirror 3 was plane, and in the second it was focusing with a focal length 1.4 m. The intensity distribution in the cross section of the unperturbed beam was close to annular. Table 1 lists the values of the inside diameter d_I of the beam at the 0.5 level, the outside diameter d_2 of the beam at the 0.5 level, the ring width $(d_I - d_2)$ at the 0.5 level, and the beam diameter d_3, measured at maximum intensity, at the entry to the chamber and in the

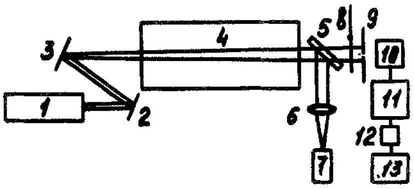

Fig. 1. Block diagram of experimental setup.

Translated from II Vsesoyuznoe Soveshchanie po Rasprostraneniyu Lazernogo Izlucheniya v Dispersnoi Srede, Tezisy Dokladov (Second All-Union Conference on Propagation of Laser Radiation in Disperse Medium, Summary of Proceedings), Part II, pp. 164-167, 1982.

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TABLE 1. Transverse Dimensions of Annular Beam (in mm)

Dimension	First run		Second run	
	at entry to chamber	in photoresistor plane	at entry to chamber	in photoresistor plane
d_I	I,6	4,3	I,2	2,7
d_2	4,5	I2,5	3,8	I0,7
$d_I - d_2$	2,9	8,2	2,6	8
d_3	3	8,3	2,5	5,8

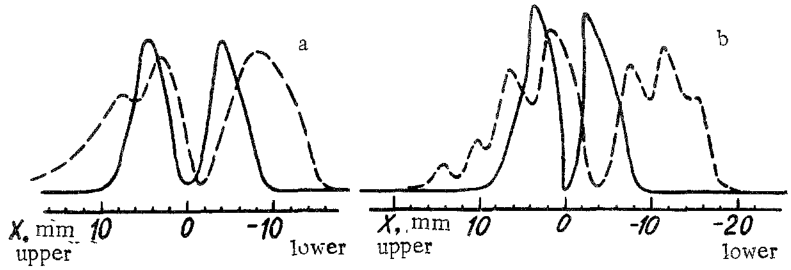

Fig. 2. Radiation intensity distributions in the transverse cross section of the beam in the photoresistor plane (a and b denote the first and second measurement runs).

plane of the photoresistor 10. The intensity on the beam axis was zero. The intensity distribution in the beam cross section was determined by scanning along a vertical line passing through the axis of the unperturbed beam. The sooty aerosol was obtained by burning engine oil, and its disperse composition was determined from measurements of the aerosol transparency at five laser radiation wavelengths (0.44, 0.63, 1.06, 3.39, and 10.6 μm).

The most probable particle radius in the chamber was $\sim 0.06 \pm 0.02$ μm, while the parameter μ of the half-width of the gamma distribution varied in the range 1-3. The optical depth of the aerosol in the chamber reached ~ 3 at $\lambda = 10.6$ μm.

Some of the experimental results are shown in Figs. 2-4. Figure 2 illustrates the experimental intensity distribution in the transverse cross section for an unperturbed (solid curves) and perturbed (dashed) beam. The coordinate X on the figure determines the distance reckoned along the scanning line from the point of its intersection with the axis of the unperturbed beam, while the dashed curves correspond to $\tau = 1.8$. The measurements have shown that with increasing τ the beam as a whole is shifted downward. Additional maxima are produced in this case between the upper and lower parts of the beam, and tend to form more readily for a relatively narrow beam. No decrease was observed in the experiments in the depth of the intensity dip of the central part of the perturbed beam. The zero-intensity point shifts downward together with the beam. Figure 3 shows the measured shift of this point $\Delta X < 0$; it amounted under the experimental conditions to several millimeters and was noticeably larger in the second measurement run.

The general character of the thermal distortions of an annular beam in sooty aerosol is illustrated in Fig. 4, which shows the lines of maximum intensity in the cross section of an unperturbed (1) and perturbed (2) beam. The beam is "squeezed" vertically, but preserves its annular structure.

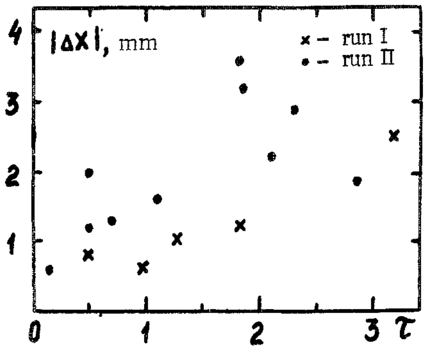

Fig. 3

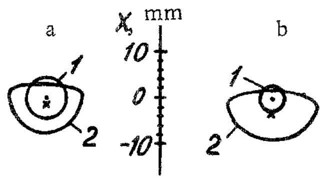

Fig. 4

Fig. 3. Shift of the zero-intensity point vs the optical depth of the aerosol layer.

Fig. 4. Distortion of annular structure of beam [a) first measurement run, b) second run; the dots and crosses show the positions of the zero-intensity point in the unperturbed and perturbed beams, respectively].

The presently available results of theoretical investigations of the thermal self-action of annular beams in absorbing media do not permit a quantitative analysis of the experimental data, although they agree qualitatively with them. The question of the minimum intensity in the central part of an annular beam that undergoes thermal distortions calls for an independent investigation.

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