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SPECIAL FEATURES OF THE INTERFEROMETRY OF RADIALLY LOADED LARGE GLASS LASER MATRICES

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We present the results of computational investigation of the loss in contrast of interference patterns of lateral shear with a reference beam. We consider the behavior of the degree of coherence over the active element cross-section and in time after starting the laser pumping system in operation, as well as the behavior of the integral degree of probing-radiation depolarization.

The well-tested methods of shearing and reference interferometry for diagnostics make it possible to obtain contrast interferograms with sufficient coherence of the illumination source and not very large wave-front gradients. In addition to phase distortions, some of the media diagnosed introduce changes into the original polarization (induced birefringence or change in the orientation of polarization), which may cause loss of contrast in an interference pattern.

As is known, birefringence implies the appearance of radiation components with orthogonal orientations of polarization [1]. Each of these components is characterized by its own amplitude-phase distribution, which depends on both the mechanism of the appearance of birefringence and the form and orientation of the probing-beam polarization. The separation of radiation into polarization components causes the appearance of two independent interference patterns, whereas orthogonality of the polarization orientations of beams leads to a simple photometric superposition of those patterns. A situation is possible in which different portions of an interferogram are formed by radiation components with different polarizations and different amplitude-phase distributions. The latter, on the other hand, depend on the degree and character of beam depolarization occurring on its passage through a birefringent medium.

In the study of the thermally stressed state of the cylindrical glass active element of a high-power solid-state laser by means of a shearing interferometer, distinct worsening of the contrast of the interference pattern was noted on interferograms in regions located at an angle of about 45° to the direction of polarization orientation of the linearly polarized probing light. Such an interferogram is depicted in Fig. 1. It was obtained 20 sec after the exposure of a glass rod (45 mm in diameter and 914 mm long) to pumping radiation with a total energy of 90 kJ. Also shown are the orientation of the probing beam polarization (the *PP* cross-section) and the direction of the lateral shear s in the interference pattern.

In a shearing interferometer [2] two pairs of beams with orthogonal polarizations superpose upon each other. Each pair forms an independent interference pattern according to the spatial distribution of the phase and interferometer tuning to a certain shear and curvature of the front. If the radiation wave fronts with orthogonal polarization components differ greatly from one another with the polarization degree being rather high, the resulting interference pattern may have regions that are characterized by a noticeable loss of visibility (in the degree of coherence $|\mu_{12}|$ at equal intensities of interfering beams [1]) in them.

To carry out a detailed study of this feature, we performed a numerical simulation of the conditions that lead to loss of contrast in the interference patterns of lateral shear with an unperturbed reference beam [2]. We calculated the two-dimensional thermally stressed state in a glass active element exposed to the effect of the external field of optical pumping. Nonuniformity of pumping leads to distortion of the probing-radiation wave front due to

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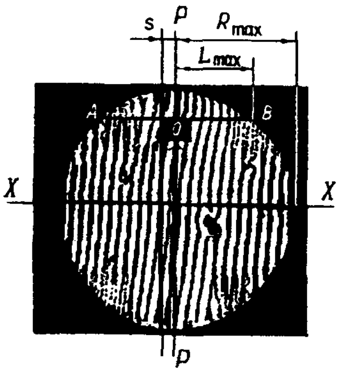


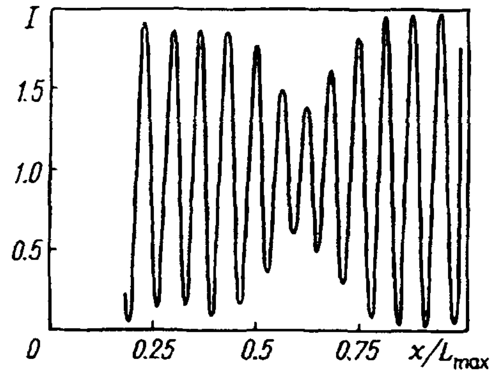


Fig. 1. An experimental shearing interferogram with regions of loss of contrast: *PP*, orientation of probing radiation polarization; *XX*, horizontal axis; *s*, magnitude and direction of lateral shear; R_{max}, radius of cylindrical active element; L_{max}, length of segment over which the calculated shearing interferogram is recovered.

Fig. 2. The resulting intensity profile on segment *OB*.

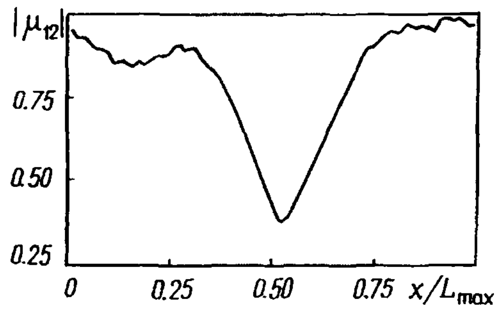


Fig. 3. Distribution of visibility in calculated interference pattern over segment *OB*.

the dependence of the refractive index of the medium on the temperature and geometric deformation of the active element [3]. As a result of the appearing photoelastic effect [1] the radiation wave fronts of each polarization component display additives that are proportional to the stresses in the substance investigated with account for the symmetry and structure of loading [4].

The amplitude and wave fronts obtained served as starting ones for reduction of the final interference pattern. The intensity profile in it was calculated at section *AOB* parallel to the direction of shearing (see Fig. 1). First, we determined the interference pattern of the lateral shear for a beam with polarization oriented parallel to the direction of shearing (the I_1 profile), and then perpendicularly to shearing (I_2):

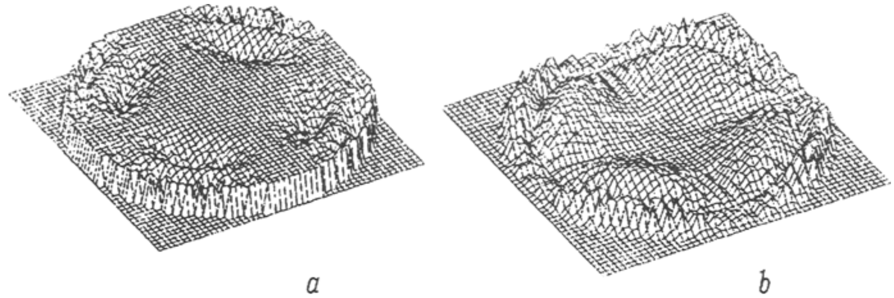
$$I_1(x) = I_{pp}(x) + I_{pp}(x+s) + 2\sqrt{I_{pp}(x)\, I_{pp}(x+s)} \cos\left[\varphi_{pp}(x) - \varphi_{pp}(x-s)\right],$$

$$I_2(x) = I_{xx}(x) + I_{xx}(x+s) + 2\sqrt{I_{xx}(x)\, I_{xx}(x+s)} \cos\left[\varphi_{xx}(x) - \varphi_{xx}(x-s)\right],$$

where x is the absolute space coordinate in the direction of shearing; s is the magnitude of lateral shear; (I_{xx}, φ_{xx}), (I_{pp}, φ_{pp}) are the intensity and phase of the components of radiation with polarization parallel and normal to the direction of shearing, respectively. The radiation components with orthogonal polarizations were added incoherently (photometrically), i.e., the resulting interference profile of the intensity was determined as

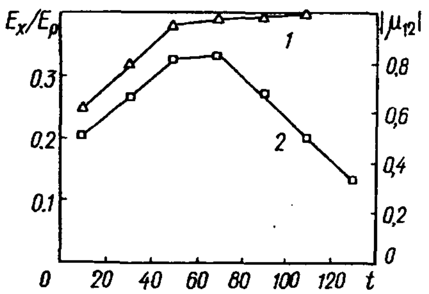
$$I(x) = I_1(x) + I_2(x).$$

The resulting profile of the intensity at section *OB* (see Fig. 1) for $s = 3$ mm and for a probing radiation wavelength of 632.8 nm is presented in Fig. 2. Comparing the position of the bands and their degrees of contrast



a *b*

Fig. 4. Calculated distributions of probing radiation amplitude: a) for polarization orientation in the *PP*



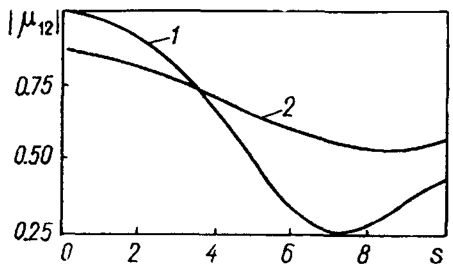


Fig. 5. Dependences of the mean-integral (over the OB stretch) value of $|\mu_{12}|$ (1) and E_x/E_p (2) of probing radiation on time after a pumping pulse. t, sec.

Fig. 6. Dependence of $|\mu_{12}|$ on the magnitude of shear s for: 1) a shearing interferometer; 2) an interferometer with a reference beam. s, mm.

on a shearing interferogram (Fig. 1) with the calculated profile of the intensity in the section selected, we can conclude that the reason for the loss in the contrast of the interference pattern was determined correctly. The distribution of the interference pattern visibility over the OB stretch is depicted in Fig. 3. The value of $|\mu_{12}|$ decreases with distance from the vertical axis. In the region close to the outer surface of the rod (at about $0.85R_{max}$ and $0.5L_{max}$ from point O over the segment OB in Fig. 1) we note a rapid decrease in coherence, which can be explained by the fact that precisely in these regions the probing radiation is most subject to depolarization leading to redistribution of the radiation energy with the original polarization into the orthogonal component (see Fig. 4).

As the temperature levels out, the stresses decrease and, consequently, the level of depolarization decreases. Figure 5 shows dependences of the mean-integral (over segment OB) degree of coherence and of the integral depolarization of probing radiation on time after a pumping pulse. Approximately at the 40th second the integral degree of coherence returns to the original state, whereas depolarization attains its maximum level over the entire area of the beam.

The presence of a maximum of depolarization is due to the fact that the strongest perturbations accumulated near the outer side surface of the rod after the pumping pulse begins to redistribute with time to the rod center due to thermal relaxation. Simultaneously, the absolute scatter of these perturbations is decreased and the area of their distribution is increased. The value of $|\mu_{12}|$ was calculated for only one AOB section separated from the horizontal axis XX by about $0.7R_{max}$. Propagating into the interior of the rod, the surface perturbations pass through this section rather rapidly. This explains the levelling out of the interference pattern and the recovery of its degree of contrast to the original level.

The magnitude of shearing determines not only the sensitivity of an interferometer to certain space scales of inhomogeneities [2], but also the distribution of visibility in an interference pattern [5]. This fact is very important and must be taken into account when tuning an interferometer for revealing certain scales of inhomogeneities in the object investigated, and in the degree of coherence of separate portions of the beam area.

Figure 6 shows the dependence of the integral value of $|\mu_{12}|$ on the magnitude of shearing for the structure of perturbations appearing in the rod. When the shear tends to zero, each point of the field is compared with itself. In this case the difference of phases remains constant and equal to zero, whereas the degree of coherence tends to unity. An increase in shearing is similar to an increase in the distance between the compared points of the beam. This, in turn, leads to a decrease in the spatial coherence, whose minimum value is observed when the interferometer ensures shearing of interfering beams over half the size of the field investigated.

As numerical investigations showed, interferometry with an unperturbed reference beam displays a similar character in the behavior of $|\mu_{12}|$ on increase in the value of disagreement (shear) of beams. Figure 6 also presents the dependence of $|\mu_{12}|$ for this type of interferometer. In contrast to a shearing interferometer, the spatial coherence in the case of zero shear of beams has a value that differs from unity, which is explained by the existence of the initial difference between the phases of the perturbed and reference beams.

Thus, the depolarization of radiation caused by nonuniformity in the transverse distribution of intense optical pumping in large laser matrices greatly influences the structure of contrast of shearing and reference interference beams.

NOTATION

$E_x/E_p = \int_\Omega A_x^2 d\Omega / \int_\Omega A_p^2 d\Omega$, integral degree of radiation depolarization; Ω, transverse area of beam; A_x, A_p, amplitudes of beams with polarizations along the XX and PP axes, respectively; $|\mu_{12}|$, degree of spatial coherence.

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