SPLIT-BEAM MODEL IN THE INVESTIGATION OF ADAPTIVE CORRECTION OF THE THERMAL SELF-ACTION OF LASER RADIATION ON EXTENDED INHOMOGENEOUS PATHS IN THE ATMOSPHERE

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A comparative analysis of the results of the split-beam model and a two-dimensional aperture model for the numerical investigation of distortions caused by thermal self-action of radiation on inhomogeneous paths in the atmosphere is performed. Scaling factors for the maximum intensity and angular displacement of the beam maximum are determined.

Numerical simulation on a computer is one of the main methods used for studying the possibilities of adaptive correction of thermal distortions of laser beams in the atmosphere.[1] The most common approach is one in which a system consisting of the nonlinear parabolic equation for the complex amplitude of the field A and the material equation, which determines the relation between the index of refraction n of the medium and the intensity of the radiation, is solved. The equation for the complex amplitude is usually solved by the method of splitting[2] together with the fast Fourier transform.

In order to reduce the computer time and to reduce the computer requirements, the model of a beam of radiation with a spatially one-dimensional aperture or the split-beam model has been proposed.[3,4,5] In this model it is assumed that the amplitude of the field along the infinitely long side of the slit is constant, while along the short side the amplitude is variable. This model was employed in investigations of correction of thermal self-action of radiation on short homogeneous paths[3,4] and in investigations of the automodulation Instability of thermal self-action in the narrow-pulse regime.[5]

In this paper we examine the use of the split-beam model for estimating the distortions and evaluating the possibilities of compensating them in the case of thermal self-action of beams with a finite transverse cross-sectional area. Properties of extended atmospheric paths, such as the nonuniformity of the index of refraction n along the optical axis of the radiation beam, scanning with the radiation beam, as well as repetitive-pulse operation of the radiation source are taken into account.

We divide the propagation path into two sections. On the first section, which includes dense layers of the atmosphere, the beam of radiation becomes distorted owing to the development of thermal self-action. On the second section of the path the beam propagates virtually in vacuum, the beam undergoes structural changes associated with transformation of the amplitude and phase distortions which are acquired by the radiation on the first section of the path, and the angular distribution of the intensity is formed.

The initial amplitude and phase distribution of the radiation for a one-dimensional (slit) aperture has the form

$$A(x,\ y) = \exp\left(-\ (x/a)^{10}\right). \tag{1}$$

Correspondingly, for a two-dimensional aperture we have

$$A(x,\ y) = \exp\left(-(x/a)^{10} - (y/a)^{10}\right). \tag{2}$$

The correcting phase distribution is found by using the phase of the radiation reflected from the object. This radiation is modeled by a beam which is wider, than the main beam and has a flat phase front at the entry into the first section of the path on the object side. The power of the reflected radiation is assumed to be low, so that it does not give rise to any changes in the index of refraction n. The width of the reflected beam is chosen from the condition that diffraction effects due to reverse passage through the first section of the path must be small.

To compare the computational results for the split-beam model and the two-dimensional aperture model, whose initial amplitude distribution is described by the expressions (1) and (2), we introduce a scaling factor for the angular displacement of the maximum intensity

$$K_{ang} = \Delta x^{(2)}/\Delta x^{(1)}, \tag{3}$$

where the upper indices 1 and 2 correspond to the one- and two-dimensional apertures. In addition, we introduce a scaling factor for the intensity at the maximum of the angular distribution

$$K_{max} = I^{(2)}_{max}/I^{(1)}_{max}\ . \tag{4}$$

The calculations were performed with the first section of the path divided into eight intervals. Figure 1 shows the coefficients K_{ang} and $K_{\max}$ versus the power.

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The results of numerical modeling of the correction of distortions caused by the thermal self-action of radiation were compared under identical conditions and for the same propagation parameters.

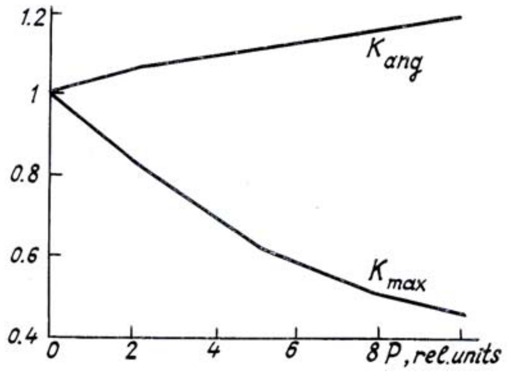

FIG. 1. The scaling coefficients for the intensity K_{ang} and $K_{\max}$ versus the power.

Figure 2 shows the change in the on-axis normalized intensity for a one-dimensional aperture and Fig. 3 shows the same thing for a two-dimensional aperture with computational grids of size 256 and 256×32, respectively, in a plane perpendicular to the optical axis. The results show that the one-dimensional model gives results that are close to those obtained for the two-dimensional model and it gives the correct qualitative picture of correction for two-dimensional beams. Based on the analysis of the results we can draw the following conclusions:

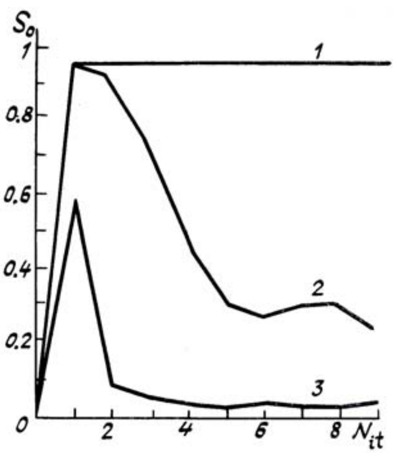

FIG. 2. The change in the on-axis normalized intensity for a one-dimensional aperture (the curves 1, 2, and 3 correspond to the per unit length radiation power of 2, 5, and 10 relative units).

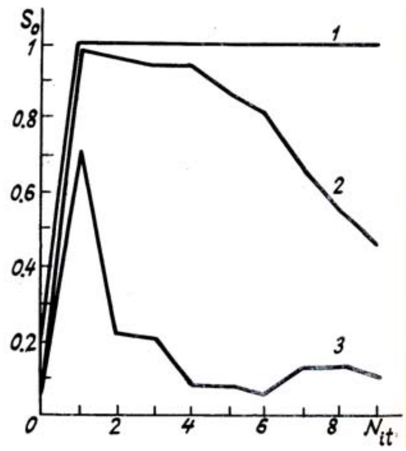

FIG. 3. Same as in Fig. 2, for a two-dimensional aperture.

1. The split-beam model makes it possible to investigate the qualitative features of the correction of thermal distortions of laser radiation on inhomogeneous atmospheric paths. This greatly reduces the computational resources required to perform the modeling.

2. Scaling factors which make it possible to estimate the effectiveness of compensation of distortions for beams with a two-dimensional aperture based on results of modeling of beams with a one-dimensional aperture for extended inhomogeneous paths in the atmosphere were obtained.

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