TECHNIQUE FOR MEASUREMENT OF GENERALIZED LASER BEAM CROSS-SECTION

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A technique for measurement of the coefficient of nonuniformity of the distribution of radiation intensity and of the generalized laser beam cross-section in terms of this coefficient is evaluated by means of a thin-wire profile bolometer. The design of the bolometer is in the form of a double lattice with mutually perpendicular elements that records output signals from each of the laser beams.

The generalized cross-section of a beam of laser emission \( S_0 \) [1] having arbitrary distribution of the cross-sectional power density \( W(x, y) \) is equal to the cross-sectional density of the equivalent beam of emission with constant power density and total power equal to the power of the physical beam. The generalized cross-section of the beam is determined by the expression

\[
S_0 = \left( \int_0^S W(x, y) \, ds \right)^2 \int_0^S W^2(x, y) \, ds = \frac{\overline{W^2}}{W^2},
\]

where \( S \) is the area of integration, equal to the area of the inlet aperture of the meter that is being used and \( \overline{W^2} \) and \( \overline{W}^2 \) are the square of the mean and mean square of the density of the incident emission, respectively.

In calibrating thin-wire bolometers used to measure the energy parameters of laser radiation with nonlinear conversion characteristic [2, 3], it is necessary to know the coefficient of nonuniformity of the distribution of the incident radiation intensity relative to the area of the inlet aperture of the device \( \delta \). The latter parameter is related to the relative dispersion of the distribution of the intensity \( \sigma_{W0}^2 \) by means of the following relation:

\[
\delta = 1 + \sigma_{W0}^2 = 1 + \frac{1}{S} \int_0^S \frac{W(x, y)}{\overline{W}} - 1 \, ds = \frac{S}{S_0},
\]

The expression in (2) shows that the coefficient of nonuniformity of the distribution of radiation intensity \( \delta \) may be determined from the generalized area of the beam \( S_0 \) and the inlet aperture of the bolometer.

If the density distribution of the radiation power may be represented in the form

\[
W(x, y) = W_x(x) W_y(y),
\]

the coefficient of nonuniformity of the distribution of the incident intensity may be expressed in terms of its components along the coordinate axes thus:

\[
\delta = \frac{\overline{W_x^2}}{W_x^2} \frac{\overline{W_y^2}}{W_y^2} = \delta_x \delta_y.
\]
The known methods of measuring the generalized cross-section of a laser beam [1] are complicated and produce quite large errors.

The present authors have considered the validity of a technique of measuring the generalized cross-section of a laser beam and the coefficient of nonuniformity of the distribution of the radiation intensity using a thin-wire bolometer. The bolometer is in the form of a two-ply square lattice with constant period of the bolometer elements. The elements of the lattice are mutually perpendicular. The coefficient of nonuniformity of the distribution of the incident intensity may be determined relative to the corresponding coordinate axes by recording the signals from each bolometer element thus:

\[ \delta_{i,j} = \frac{1}{n} \sum_{i,j=1}^{n} \left( \frac{U_{i,j}}{U_{i,j}} \right) \]

where \( n \) is the number of elements in each lattice; \( U_{i,j} \) are the signals of the bolometer elements having positional coordinates \( x_i \) and \( y_j \); and \( \overline{U_{i,j}} \) is the mean value of the signals of the corresponding lattices.

Once the coefficient of nonuniformity of the distribution of radiation intensity \( \delta \) is known, the generalized cross-section of the optical beam \( S_0 \) may be found using relation (2).

If the distribution of the radiation intensity \( W(x, y) \) does not satisfy (3) and if it cannot be extended along the coordinate axes, application of the two relations (4) and (5) leads to understatement of the value of the coefficient of nonuniformity of the distribution of radiation intensity \( \delta \) and overstatement of the value of generalized cross-section of the radiation beam \( S_0 \). The systematic error will be maximum if the radiation distribution can be made prolate in the angular directions \( \pm \pi/4 \) relative to the angular directions of the bolometer elements of the lattice.

If the center of a rectangular coordinate system coincides with the centers of the lattices and if the coordinate axes coincide with the directions of the bolometer elements, the Gaussian beam of optical radiation with power density distribution

\[ W_{x,y} = \frac{P}{2 \pi \sigma^2} e^{-\frac{x^2 + y^2}{2 \sigma^2}} \]

where \( P \) is the total power of the beam and \( \sigma \) its mean-square radius under the condition that the length of the bolometer element is greater than \( 6\sigma \) has, by (1), generalized cross-section \( S_0 = 4\pi \sigma^2 \), i.e., the area of a circle with radius equal to half the mean square radius of the beam.

It is easily proved that a circular beam of radius \( R \) and uniform distribution of radiation intensity has a mean square radius \( \sigma = R/2 \) and that its generalized area will be \( S_0 = \pi R^2 = 4\pi \sigma^2 \).

Consequently, the generalized cross-sections of beams with entirely different density distributions of radiation power are expressed by means of the same formulas in terms of their mean square radii. It may be concluded that the generalized cross-section of an optical beam with arbitrary radiation power distribution may be determined from its mean square radius.

From the recorded signals derived from a profile bolometer, the mean square radii of a beam in two mutually perpendicular directions \( \sigma_x \) and \( \sigma_y \) may be determined on the basis of the positional coordinates of the bolometer elements of the lattices and their output signals, normed by their sum along the corresponding coordinate axes. The mean square radius of a beam of radiation will be defined as the geometric mean of \( \sigma_x \) and \( \sigma_y \):

\[ \sigma = (\sigma_x \sigma_y)^{1/2}. \]

We may confirm this conclusion by means of a numerical experiment using circular beams with uniform and Gaussian distributions of radiation intensity, as well as with two analogous beams with centers displaced some distance and having the same radiation intensity. The computations were performed for a two-ply square lattice with 16 bolometer elements in each lattice and period \( \lambda \). The coordinate origin of the rectangular coordinate system was at the center of the lattice and the coordinate axes were parallel to the bolometer elements. The length of each bolometer element was \( 2l_0 \), the period \( \lambda = l_0/8 \), and the area of the lattice \( S = 4l_0^2 \).

For beams with uniform distribution of radiation intensity and radii \( r = 5\sigma \), the coefficient of nonuniformity of the incident radiation \( \delta_1 \) was calculated from the density distribution of the radiation power on the basis of the area of the inlet aperture of the radiation meter and the distance \( d \) between the centers of the beams, the profile distribution of the intensity \( \delta_2 \) once the

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