Numerical investigation of influence of photoelastic effect induced by thermal stresses on optical characteristics of anisotropic elements of solid state lasers.

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A method of numerical simulation of thermooptical distortions in various optical elements is reported. Investigations for KDP electrooptic shutters are presented.

Optical devices are heated nonuniformly while operating either by laser generated radiation (like electrooptic shutters) or by an external heat source (laser rods, acoustooptic cells etc.) Inhomogeneous temperature fields and thermal stresses due to photothermoelastic effect cause birefringence which results in aggravation of light transmission characteristics of such elements. This effect is estimated by depolarization factor A_d — light intensity loss per pass through the element placed between 2 crossed polarizers[1]:

$$A_d = \int_S I(x,y)\sin^2 2\theta(x,y)\sin^2(\delta(x,y)/2)dS \bigg/ \int_S I(x,y)dS \qquad (1)$$

where $I(x,y)$ — light intensity distribution ; $\theta(x,y)$ — rotation angle of the index ellipsoid in the cross section plane; $\delta(x,y)$ — phase shift between own linear polarizations gained on the length of the optical element.

The unconnected plane thermoelasticity problem is solved numerically by means of Finite Elements Method (separately for temperature field and for stresses field). Plain strain assumption is made for rod-shaped optical elements and plain stress for disk-shaped ones. For temperature field calculation isoparametrical lagrangian triangular finite elements with 6 degrees of freedom are used. Analogous subparametrical elements with 20 degrees of freedom represent translations. It means that temperature, stresses and cartesian coordinates are approximated by full 2-order polinomials; translations — by 3-order ones. Only such approximations are valid for this task. When this is made, changes of optical index ellipsoid are computed according to the known formulae[1] and depolarization factor— according to (1). Anisotropic material properties are considered on each stage of computation.

For electrooptic shutters the depolarization factor represents the change of the transmission due to thermal distortions[2]. For KDP shutters this change is equal in open and closed state. It is shown that a gaussian light beam may cause almost 50% greater depolarization than a spatially uniform one at the same total power in steady state and in transient case. The cross section shape was found to produce slight impact on transmission changes.

1. M.A. Karr. Applied Optics, vol.10, N 4, pp. 893–895, 1971.
2. I.P. Kaminow. Applied Optics, vol.3, N 4, pp. 511–515, 1964.