Optimization of resonator mirrors of powerful lasers

Igor Demkovych, Halyna Petrovska

Abstract - **The software for modeling temperature fields and appropriate to them deformations in optical elements of powerful lasers is developed. Carried out theoretical and experimental researches of thermal deformations in mirrors of powerful lasers, are determined major factors, which influence size of thermal deformations, the optimization of resonator mirrors designs and conditions of their cooling is carried out.**

***Keywords* - laser, resonator mirrors, deformation, modeling/**

The modeling of displacement in a sample under action of powerful laser radiation will be carried out stage by stage by account of a thermal field, and then of movings caused by this field. For the solving of these equations the method of final differences is used. In a fig. 1 the simulated temperature field in a resonator mirror of laser is submitted which arises at action of a beam with power 100 W on a resonator mirror and superficial absorption of a mirror 0,1%.

I. INTRODUCTION

One of the factors, which are necessary for taking into account at designing powerful lasers, are the thermal effects in optical elements, which arise under action of powerful laser radiation. The thermal distortions in resonators result in deterioration of the power and spatial - temporary characteristics of radiation, change of durability of resonators and even to destruction of optical elements.

II. RESEARCHES OF THERMAL DEFORMATIONS IN RESONATOR MIRRORS

For realization of theoretical researches the interconnected mathematical model is constructed and the software is developed which permits to simulate temperature fields and fields of deformations, appropriate to them, in optical elements with taking into account any spatial - temporary distributions of laser radiation, superficial and volumetric absorption, and also features of heatsink from surfaces of an optical element.

$$\begin{cases} \mu\nabla^2\vec{u} + (\lambda+\mu)\,\mathrm{grad}\ \mathrm{div}\ \vec{u} + 2\,\mathrm{grad}\ \mu\cdot\Pi_\varepsilon + \mathrm{grad}\ \lambda\ \mathrm{div}\ \vec{u} - \\ \mathrm{grad}\ [(3\lambda+2\mu)\alpha_T(T-T_0)] - \rho\ddot{\vec{u}} + \vec{F} = 0 \\ \nabla^2 T + \dfrac{\omega_0}{\lambda_q} - \dfrac{1}{a}\dot{T} - \dfrac{(3\lambda+2\mu)\alpha_T T_0}{\lambda_q}\,\mathrm{div}\ \dot{\vec{u}} = 0 \end{cases}$$

The system of the interconnected equations, which under the certain initial and boundary conditions describe change in space and time of fields of displacement and temperatures, looks like. The equation describes displacement of points of a sample under action of a temperature field described by the equation. Here: T - temperature; $\dot{T}$, $\ddot{T}$ - derivative on time; T_0 - initial temperature of a sample; $\vec{u}$ - vector of displacement; λ, μ - Lame factors; n - Poisson factor; E - Jung module; grad $\mu.\Pi_\varepsilon$ - scalar multiplication of deformation tensor Π_ε on a vector grad μ; $\vec{F}$ - volumetric forces inside a sample (source of tensions); ω0 - specific volumetric capacity; a - factor of thermal diffusivity; C – heat capacity; ρ - density of a material; λ_q - heat conductivity; α_T - factor of thermal linear expansion of a substrate material.

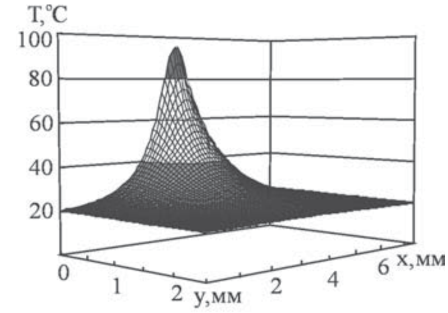

Fig.1 The temperature field in a resonator mirror of argon laser

III. CONCLUSION

The results of researches testify that action of a powerful laser beam on the resonator mirror causes lens effect conditioned by local superficial deformation of a mirror and heterogeneity of distribution of a refraction index of a substrate. The size of these distortions depends both on size of the absorbed power, and on the characteristics of a material of a substrate (coefficient of thermal linear expansion, heat conductivity, thermal and optical characteristics etc.). Temperature on a surface of a mirror depends on factor of superficial absorption: $T_{max} \sim \alpha_c$; half-width of a temperature flank, and also temperature at the center of a beam at constant value of superficial absorption factor are defined by heat conductivity factor of a substrate material: $\rho_T \sim \lambda_q$; $T_{max} \sim 1/\lambda_q$; the size of deformation of a mirror surface at constant temperature distributions is defined by factor of thermal expansion of a substrate material.

The most effective ways of reduction of thermal deformations of resonator mirrors are, first, reduction of value of superficial absorption. With this purpose it is necessary to use for thin film deposition materials with extreme low absorbing ability, and for lasers, which generate on several lengths of waves to take into account also band properties of interference structures. Secondly, for substrates of mirrors it is necessary to use materials with high enough heat conductivity and low value of factor of thermal expansion. Thus, at the given value of power of laser radiation the minimal superficial deformations will be achieved at the minimal value of parameter $\alpha_c \times \alpha_T / \lambda_q$.

In work was carried out also research of influence on a temperature field of features of heatsink from a mirror.

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