M. Ganjali

DEVELOPMENT OF COMPUTATION OF NEW DESIGN OF RESONATOR

It is well known, that a slab design of the active elements of solid-state lasers permits to solve the thermooptical problem (which restrict an output power of such lasers) and to increase homogeneity of excitation of whole volume of active media. So it is very important to find out some novel resonator designs for slab lasers, especially with diode pumping. Our main idea consists in a proposal of some schemes, which use reflections from the side walls of the crystal to make a stable multipass resonator and to extract the whole energy, which are stored in the active media. In work [1, 2] is offered new design of resonator which consists of two identical one-dimensional mirrors inclined to each other under a corner α and exterior mirror located the angle φ to one of them (fig. 1*a*). In this resonator, in the presence of a beam from 3-rd mirror, laser beam is propagated, alternately being reflected from each of side mirrors (with a diminution of an incidence angle after every reflection on 2α). After N of reflections (where $N = 1 + \varphi / \alpha$) the incidence angle will be equal to zero – and the beam is propagated backward through the same path and all picture will be repeated down to an output of a part of radiation through a mirror 3. Here it is necessary to note two important factors in during reflection:

1. When the wave arrives at the second mirror some power will be lost in reflection due to the finite conductivity of the mirror and some power will be lost by radiation around the edges of the mirror. For oscillation to occur, the total loss must be less than the power gained by travel through the active medium.

2. At the same time the phase is changing due to changing of incidence angle.

Thus diffraction loss and phase shifts are expected to be important factors, both in determining the start-oscillation condition, and the determining the distribution of energy in the resonator during oscillation.

According to method of Fox and Li [3] for calculation of field distribution, our offering resonator is equivalent to the case of a transmission medium comprising a series of collinear identical mirrors with different reflection coefficient cut into parallel and not equally paced black partitions of infinite extent, as in fig. 1*b*.

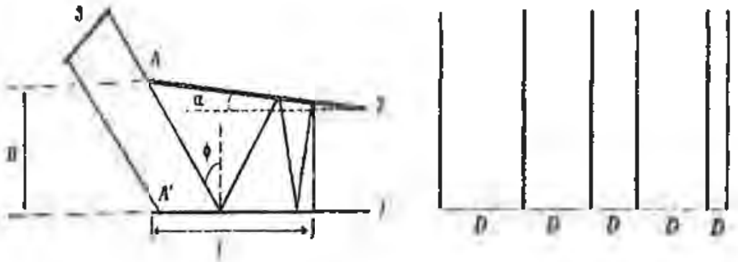


Fig. 1. The new resonator and the transmission medium analog

The expressions connecting N to angles α and φ, and also length of a beam in active media for one pass from point A up to point B are given below.

$$N = 1 + \varphi/\alpha, \tag{1}$$

$$l = d\{\frac{1}{\cos\varphi} + \cos(\varphi+\alpha)\sum_{k=1}^{\varphi/\alpha}\{\cos[\varphi-(k-1)\alpha]\cos(\varphi-k\alpha)\}^{-1}\}, \tag{2}$$

where d – size of the entrance aperture of active substance.

The ratio for length L of a mirror 1, and, hence, and minimal length of active media, at which is provided the complete repeating of beam path at return course, is following:

$$L = d[\mathrm{ctg}\,\alpha - \cos(\varphi+\alpha)/\sin\alpha]. \tag{3}$$

Last piece of a beam is perpendicular to a mirror 1 or 2 in case of odd or even N accordingly. Its length l_N is defined by ratio

$$l_N = d\cos(\varphi+\alpha)/\cos\alpha. \tag{4}$$

For a beam which is included in active media in a point A' of a mirror 1, the expression for length l' ways this media looks like

$$l' = d\cos\varphi\cos\alpha\sum_{k=1}^{\varphi/\alpha}\frac{1}{\cos[\varphi-(k-1)\alpha]\cos(\varphi-k\alpha)}. \tag{5}$$

We assume at first an arbitrary initial field distribution at the first mirror and proceed to compute the field produced at the second mirrors as a result of the first transit. The newly calculated field distribution is then used to compute the field produced at the first mirror as a result of the second transit. This computation is repeated over and over again for subsequent successive transits. We shall use the scalar formulation of Huygens principle to compute the electromagnetic field at one of the mirrors in terms of an integral of the field at the other This is permissible if the dimensions of the mirror are large in terms of wavelength ($\lambda \ll a \ll D$). The field distribution in the second mirror is:

$$E_2(x_2) = \frac{\exp(-i\pi D/\lambda)}{(D\lambda)^{\frac{1}{2}}} \int \exp\left(\frac{-i(x_2 - x_1)^2}{D\lambda}\right) E_1(x_1) dx_1 \qquad (6)$$

Where a-size of surface on axis x. for any resonator, if distribution field $E_1(x_1)$ of the first mirror is well known, it is possible to define distribution field $E_2(x_2)$ on the second mirror with the help of equation (1); having repeated this procedure and we received distribution field $E_3(x_3)$.

$$\gamma E(x_1) = \frac{1}{D\lambda} \int K(x_1, x_3) E_3(x_3) dx \qquad (7)$$

and K:

$$K(x_1, x_2) =$$

$$\int \exp\{\frac{-i\pi}{D\lambda}[2\delta_2 x^2 - 2(x_1 + x_3) + \delta_1(x_1^2 + x_3^2) + \xi_1(x_1 + x_3) + 2\xi_2 x]\}, \quad (8)$$

Where D distance between mirrors, λ – wavelength, ξ_1, ξ_2 inclined angle of mirrors and $\delta = 1 - D/R$. Eigenfunction E_n of the equation definite field distribution on the first mirror after the closed round of the resonator and eigen-values γ_n, loss value $\beta_n = 1 - \gamma_n^2$ for every type of oscillation. In computer was programmed to solve the integral equations. We shall use this calculation for a system, which is formed by 2 same one-dimensioned mirrors, curvature and also inclined one to the other under the angle ξ, with a diaphragm inside it (fig. 2*a*). And also for a system is consisted by two difference mirror, which located in distance D from each other and also inclined to axis under corner ξ_1, ξ_2 (fig. 2*b*).

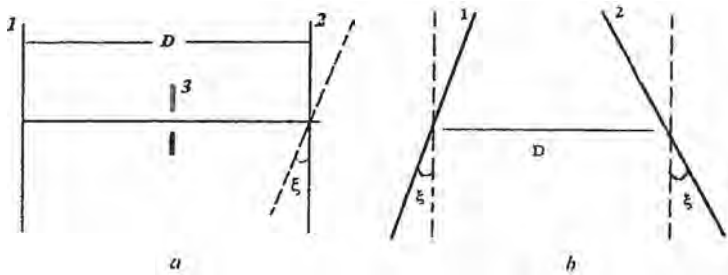
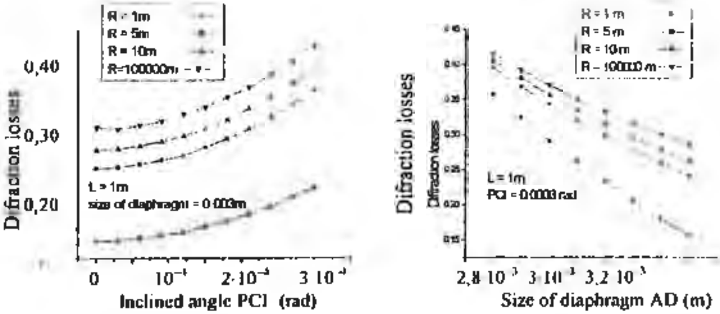


Fig. 2. The inclined resonators



a *b*

Fig. 3. Independent the lowest order of mode diffraction losses on inclined angle (*a*) and size of diaphragm (*b*) for fig. 2*a*

Fig. 3*a*, *b* shows calculated diffraction losses for system (fig. 2*a*) as a function of size of diaphragm and inclined angle mirrors for difference curvature mirrors. The carried out accounts show, that, as well as it's to expect, with increase of inclined angles, losses will increase.

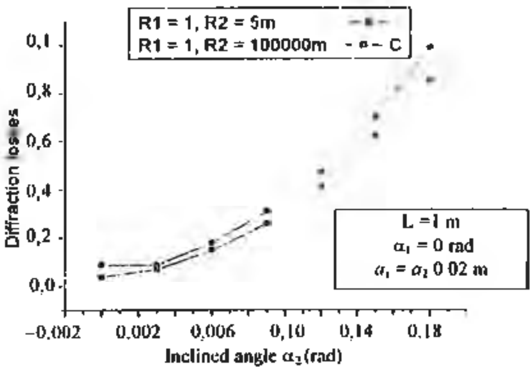
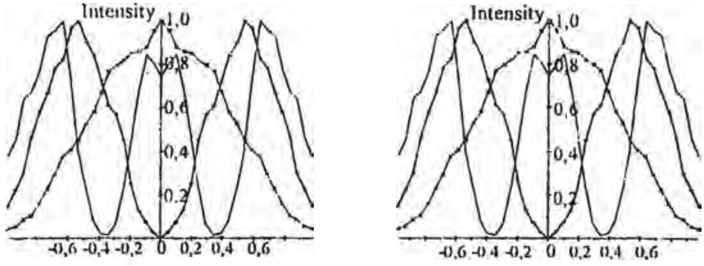
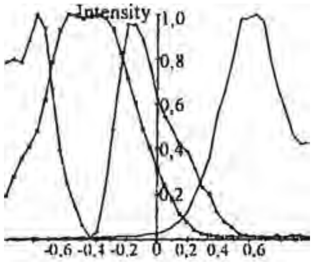


Fig. 4. Independent the lowest order of mode diffraction losses on inclined angle α_2 for fig 2 (*b*)



(a) (b)



(c)

Fig. 5. Diametrical field distribution for resonator (fig.3) for 3 first mode of the lowest order with $a_1 = a_2$ and R_1 = 1 m, R_2 = 100000 m, accordingly at inclined angle $\xi_2 = 0$ and (*a*) ξ_1 =0 rad, (*b*) ξ_1 =0.003 rad and (*c*) ξ_1 = 0 018 rad
• – moda 00, + – moda 01,
-- moda 02

In an obvious kind the dependence of diffraction losses for system (fig. 2 *b*) as a function of inclined angle α_2 is shown in fig. 4. Also diametrical field distribution for resonator (fig. 3) for 3 first mode of the lowest order is shown in fig. 5. Evidently with increasing inclined angle, intensity distribution remains asymmetry.

So the computer technique we employed is general and versatile. It can be used to study the effects of aberration and misalignment.

References

1. *Жуковский В.В., Некрашевич Я.И., Орлов Л.Н.* О возможности создание малогабаритных волноводных твердотельных лазеров // Лазерная физика и спектроскопия. Тр. онф.: Т. 1. Под ред А А. Афанасьева Минск 1997. С. 216–264.
2. *Orlov L.N., Zukovskij V.V, Necrashevich Ia.I.* Novel schemes of slab solid-state lasers // CLEO/Europe'98 Technical Digest, Glasgow: 1998 P 163
3. *Fox A., Li T.* Resonant modes in a maser interferometer // The Bell System Technical Journal. 1961. Vol. 40. P 453