

# Laser on the big solar concentrator

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## ABSTRACT

The possibility of application of Nd:YAG active elements with large sizes for pumping by the concentrated solar flux on the Big Solar Furnace NPO "Physics – sun" (Tashkent) is considered. For solution of the problem the numerical experiments were carried out and the various variants of laser design had been considered.

**Keywords:** laser, solar, secondary concentrator, Nd:YAG

## 1. INTRODUCTION

One of effective laser materials for direct transformation of solar radiation into the laser is Nd:YAG crystal. However, the difficulties of growth of crystals of the large sizes compared to the size of a focal spot of the large solar concentrators such, as Big Solar Furnace (BSF) NPO "Physics - sun" makes their application not effective in similar concentrators.

Recently developed technology of manufacturing of laser materials on a ceramic basis [1] has opened new opportunities of creation of powerful solar pumped lasers. The technology not only is easier, but also does not limit the form and sizes of active elements. In this paper the possibility of application of Nd:YAG active elements with large sizes for pumping by the concentrated solar flux on the BSF NPO "Physics - sun" (Tashkent) with total power up to 1 MW of a solar flux on a focal plane with a diameter  $\sim 40$  cm and a disclosing angle of  $\sim 70^\circ$  is considered for the first time. For solution of the problem the numerical experiments were carried out and the various variants of a laser design had been considered.

The design of the Nd:YAG laser of which scheme are considered are presented in fig.1. It consists of several parallel located active elements of cylindrical form and secondary concentrators, established in focus (fig.1b).

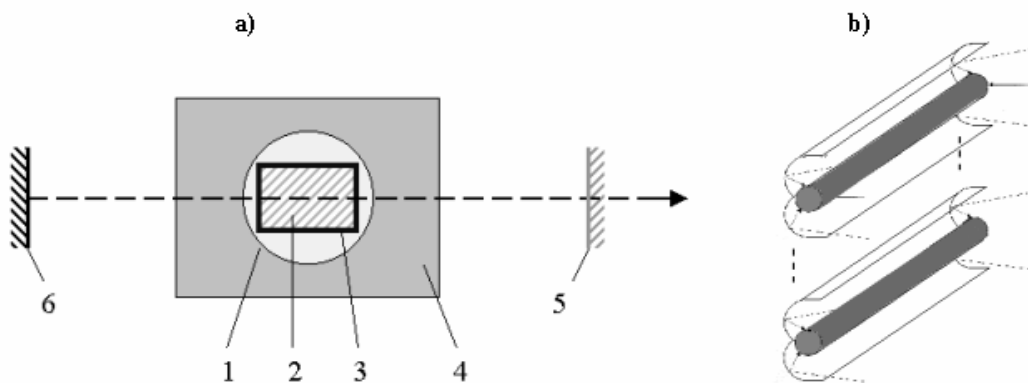


Fig.1. a) Pumping schemes of the active elements. 1- focal spot of BSF, 2- battery of active elements (rods) with secondary concentrators, 3-diaphragm, 4-cooled shield, 5,6 - mirrors, b) Battery of active elements (rods) and secondary concentrators.

## 2. COMPUTER SIMULATIONS

The calculations of parameters of the solar laser system were carried out in two stages: calculations of absorbed power and distribution of population inversion in an active element; calculations of factors of amplification at the given absorbed power and distribution of population inversion;

For performance of the first stage the method of Monte-Carlo has been used and numerical experiments were carried out. The randomizer generates the wavelength of incident photon, the reflection and absorption coefficients in the secondary concentrator (SC) and in an active element, the photon track length so long as it not will be absorbed in an active element (or in the secondary concentrator), or leaves the system. The randomizer also set the initial photon coordinates according to intensity distribution at the focus of BSF, the fall angle (within the limits of a discosing angle of BSF) of solar beam on a plane of diaphragm (fig.1a) (on a plane of the entrance aperture of secondary concentrators with an active element rods (fig.1b)). The reflection coefficient of an internal surface of the secondary concentrators was assumed equal 80%. The radial distribution of intensity on focus of BSF approximately can be expressed as:

$$I = I_0 \exp(-r^2 / 200) \quad (1)$$

As the solar radiation is not monochromatic and represents a broadband spectrum of radiation that in computations in the rough approximation it is possible to use average wavelength of solar radiation and average value of an absorption coefficient. However for exacter calculations it is necessary to take into account all spectrum of solar radiation and spectrum of absorption of active medium from which the absorption coefficient appropriate by everyone value of wavelength of radiation is defined. In calculations the absorption spectrum (coefficients) of active medium and a spectrum of solar radiation were taken into account. For account a solar spectrum and absorption spectrum it was generated a random number (wavelength) with distribution appropriate to a solar spectrum and it was defined the absorption coefficient for the given value of wavelength from an absorption spectrum.

Thus, the absorbed part of falling solar radiation and distribution of population inversion are defined. Using these results in the second stage, the factors of amplification of a small signal in various points of a focal spot of BSF were calculated.

## 3. RESULTS OF NUMERICAL EXPERIMENTS

Results of first stage of calculations are presented in fig 2.

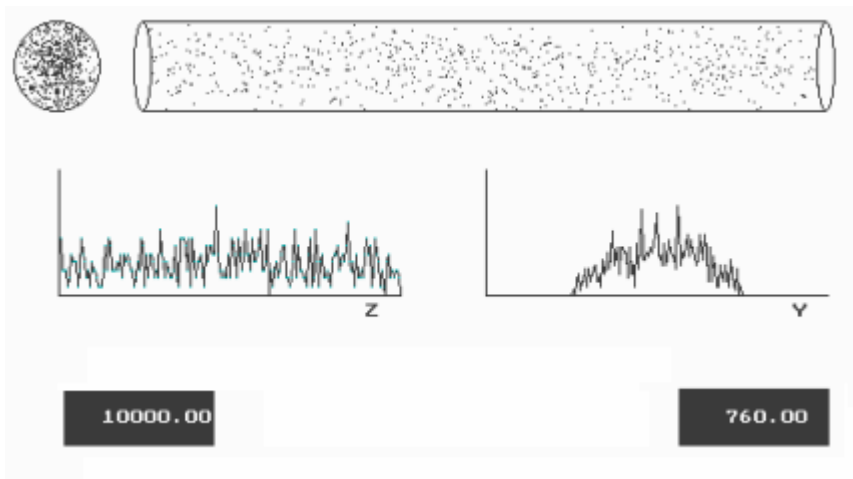


Fig.2. Distribution of inverse atoms in a rod with a diameter 1 cm and length 20 cm for SC (fig.1b), established at the center of focal spot of BSF (Distribution on axis Z - along the length of an active element, Y-transverse coordinate). Figure 10000- total considered photons in a range of wavelengths from 0 up to 1000 nm, 760-amounts of absorbed photons.

Total absorption coefficient in a range of wavelengths from 0 up to 1000 nm for SC (fig.1b) with an active element of cylindrical form equal to  $\sim 8\%$ . Using results of modeling of absorption in laser rods and after normalization on a complete spectrum of the sun the calculations of a small-signal single-pass gain of active elements with different length established in various distances from the center of a focal plane of BSF were carried out.

It was supposed, that the end faces of active elements are covered with anti-reflecting coatings and the losses at the expense of reflection at the end faces are  $\sim 1\%$ . Taking into consideration the lasing wavelength loss  $a$  the small-signal single-pass gain was determined as:

$$G = \exp[(g - a)L - 0.01], \quad (2)$$

where  $g = a N$  is gain coefficient,  $L$  is rod length,  $c$  -stimulated emission cross-section and  $N$  is the inverted Neodymium ions concentration (population inversion),  $a = 0.001 \text{ cm}^{-1}$ .

At deriving the population inversion in an active element the mean pumping efficiency 0.76[2] that defines the fraction of absorbed photons that produce upper-state atoms that participate in the lasing process was taken into account. The obtained results for 13 active elements are plotted in fig.3.

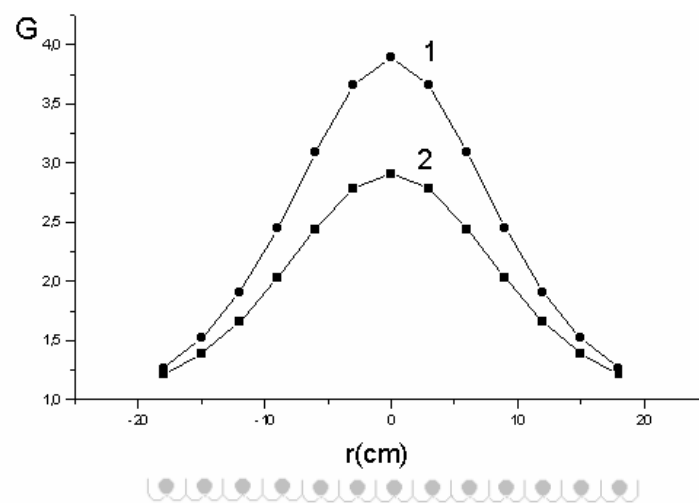


Fig.3. Small-signal single-pass gain for Nd:YAG active elements as a function of position of rods with diameter  $d=1\text{cm}$ . 1- $L=30\text{cm}$ , 2- $L=20\text{cm}$ . The maximal solar flux  $I_0=750\text{W/cm}^2$ ,  $r$ -distance from center of focal plane of BSF to the rod center position. In the bottom of figure the cross-sections of active elements with SC are shown.

For the total small signal single-pass gain for 13 active elements with  $L=20\text{cm}$  and  $L=30\text{cm}$  we have 4290 and 40380 respectively. Above listed results shows that at the appropriate maintenance with a cooling system the Nd:YAG laser materials with large sizes can be used for effective transformation of a solar energy of concentrated solar flux of the BSF NPO " Physics - sun " to energy of laser radiation.

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