THERMOOPTICAL DISTORTIONS IN END-PUMPED ND:YAG SLAB LASER

A.D. Lyashedko*, D.A. Lisicin, V.F. Seregin, V.B. Tsvetkov and I.A. Shcherbakov

A.M. Prokhorov General Physics Institute, Russian Academy of Sciences, Moscow, Russia

*Corresponding author: e-mail: lyashedko@mail.ru

Efficient operation of diode-pumped solid-state lasers with both high average power and good beam quality is generally limited by thermal effects in the laser gain medium. The effects of these distortions can be mitigated by application different pumping and extraction architecture. Zigzag slab lasers (see, for example, [1,2]) have demonstrated near-diffraction-limited output power at above 1 kW, because zigzag propagation by means of total internal reflections (TIR) eliminates thermally induced optical path differences over the entire beam area [3].

In experiment we have used the composite active slab made of three parts by a method of diffusion bonding. The central 40-mm length of the slab is 0.8 % Nd:YAG, with 11-mm-long diffusion-bonded undoped YAG end caps that reduce end effects. End faces of the slab have been cut under 45°, for use of a longitudinal pumping. Special polymer has been put on TIR planes to reduce losses at total internal reflection of a laser beam. The pumping was symmetrically organized from both faces with two set of laser diode modules.

Temperature distribution along the optical axis of the slab was studied by the interferometric technique. The steady state interference pattern allows to observe temperature distribution along the slab corresponding to the some pumping rate. While using the interferometric method it is possible to calculate the real temperatures along the slab at different absorption coefficients (fig.1). This temperature profile does not effect the lasing efficiency and beam quality in the case of homogeneous pumping distribution in a slab cross-section. But high values of the temperature gradient along slab can lead to the slab fracture.

Thermooptical distortions of the HeNe probe beam were experimentally estimated at different absorbed pump power distribution in slab cross-section. We used two methods to estimate value of the thermal lens: method of multiple narrow probe beams and interferometric method. It was shown that high nonuniform absorption pump power distribution in slab results in focusing even in zigzag direction. Using more uniform distribution (Fig. 2a) with 3-lens pump focusing system allowed to reduce thermooptical distortions to less than 1 wavelength (λ=632.8 nm, Fig. 2b) in zigzag direction and in several times in non-zigzag plane (at absorbed pump power 380 W).

Experimental investigation of losses in slab with zigzag beam path was done. It was shown that the main factor is the loss in the protective layer deposited on the TIR of the active element. Using SIEL type polymer as a protective coating on the TIR was proposed.

Measurements of the small signal gain in zigzag slab amplifier were made at different pumping conditions. At effective pump absorption coefficient 0.7 cm⁻¹ gain was \( g_d = 0.7 \) at 350 W pumping. Four-pass slab amplifier was realized with \( g_d = 2.3 \) in continuous wave. The main factor limited gain in multiple-pass amplifier was influence of the thermal lens and cutting of the beam at the slab aperture.

In the case of inhomogeneous pumping in the slab the 3-D thermal lens was arrived. Its appearance and influence is clearly seen when using the pulsed pumping instead of CW. In plane cavity there was no lasing at pump power more than 200 W in CW because of high value of thermal lens optical power. Using more uniform absorbed pump power distribution in slab cross-section (Fig. 2a) we observed lasing with output power more than 100 W with 34 % slope efficiency at absorbed pump power around 400 W and there was no thermal lens influence on output characteristics (Fig. 3).

Fig.1 Temperature profile along the slab at 200 W pumping with different pump absorption coefficient (*\( \alpha_{eff} = 2 \) cm⁻¹, \( \alpha_{eff} = 0.9 \) cm⁻¹).

Fig.2 (a) - Distribution of absorption pump power in slab cross-section in case 3-lens pump focusing system (b) - thermooptical distortions of probe beam at 380 W pumping.

Fig. 3 Input-output curve for Nd:YAG slab laser with homogeneous pumping in continuous wave mode.

