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Laser diode array (LDA) end-pumped multi-watt Yb:YAG 1030 nm laser

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A LDA (laser diode array) end-pumped Yb:YAG 1030 nm laser is reported. Using a plano-concave resonator, with input pump power of 11.79 W, 2.55 W TEM_{00} continuous wave laser at 1030 nm was obtained. The effective focal length of the thermal lens is also calculated.

Keywords: all-solid-state laser, Yb:YAG, 1030 nm.

1. Introduction

With the rapid development of high power, high brightness InGaAs laser diode emitting at 940 nm, researchers began to notice the immense potential of Yb:YAG laser crystal. Compared with Nd^{3+}-doped crystals, Yb:YAG has many advantages [1], such as, a much longer upper laser level state lifetime (0.95 ms), higher quantum efficiency (91.4%) and very broad absorption band (18 nm). So it is more suitable for laser diode pumped solid-state high power and high efficiency laser [2–4].

Figure 1 shows the absorption and emission spectral properties of Yb:YAG crystal [5]. There are two main emission peaks in Yb:YAG crystal: one is at 1030 nm, and another is at 1049 nm. There is also an apparent reabsorption peak at 1030 nm, and it will give rise to a higher threshold at this point. In order to reduce the reabsorption, Yb:YAG must be cooled in the experiment. A multi-watt 1030 nm laser cooled by circulating water has been reported by YANG *et al*. [6]. In this paper, an air cooled 2.55 W 1030 nm laser is reported with the input power of 11.79 W.

2. Calculation on thermal lensing effect

For high power solid state laser, the thermal lensing effect can change the mode of the laser, and even draws it work unstably. So the thermal lensing effect is an important

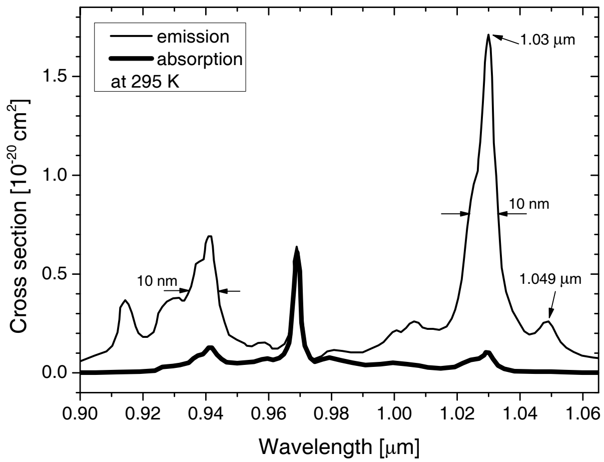

Fig. 1. The absorption and emission spectral properties of Yb:YAG.

parameter for the high power solid state laser. The effective focal length of the thermal lens can be expressed by [7]:

$$f = \frac{\pi K_C \omega_p^2}{P_{\text{th}}(\mathrm{d}n/\mathrm{d}t)} \frac{1}{1 - \exp(-\alpha l)} \tag{1}$$

where K_C is the thermal conductivity of the laser material, ω_p is the pump-beam radius, P_{th} is the fraction of the pump power that results in heating, and dn/dt is the change of refractive index with temperature. In this experiment, the Yb:YAG laser crystal is 10 at.% doped with dimensions of $\Phi = 4\times1$ mm^3. Its material parameters are dn/dt = = 8.9×10^{-6} K^{-1}, $\alpha = 9.9$ cm^{-1}, $K_C = 0.14$ W/cm. The pump-beam radius ω_p is 200 μm. We assume that 9% of the input pump power results in heating. The theoretical focal length of the thermal lensing with the change of input pump power is calculated and

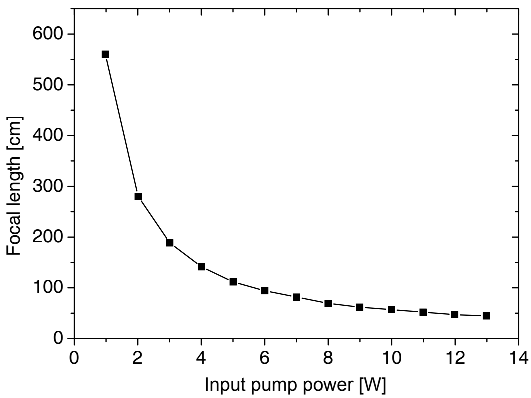

Fig. 2. Change of the focal length of the thermal lens with input pump power.

shown in Fig. 2. In this experiment, the maximum input pump power is 11.79 W, so the shortest focal length calculated by Eq. (1) is 48 cm.

3. Experiment and results

Figure 3 shows the schematic diagram of the LDA pumped Yb:YAG 1030 nm laser. The pump source is a fiber-coupled 940 nm LDA with a core diameter of 400 µm and numerical aperture of 0.22 from LIMO Company. In the experiment, its maximum output power is 13.25 W. Two lenses with focal lengths of 40 mm were used to focus the pump beam on the Yb:YAG crystal. The front face of Yb:YAG has high transmission at 940 nm ($T = 88.9\%$) and high reflectivity at the wavelength of 1030 nm ($R = 99.9\%$), and its rear face has an anti-reflective coating for 1030 nm ($T = 99.9\%$). The output coupler has a high reflective coating for 1030 nm ($R = 95\%$). The mirror curvature radius is 100 mm. The front face of Yb:YAG and the output coupler mirror compose a plano-concave resonator. In the experiment, Yb:YAG was fixed on a copper holder, which was mounted on a thermo-electric cooler (TEC) as a heat sink. The TEC was cooled by air. The temperature of Yb:YAG was controlled at 20.0 °C with a control accuracy of 0.1 °C.

With an input pump power of 11.79 W, 2.55 W TEM_{00} laser at 1030 nm was obtained, and the optical conversion efficiency was 21.7%. The output power as a function of input power is shown in Fig. 4. The threshold is 3.47 W and no saturation phenomena occur in our experiment.

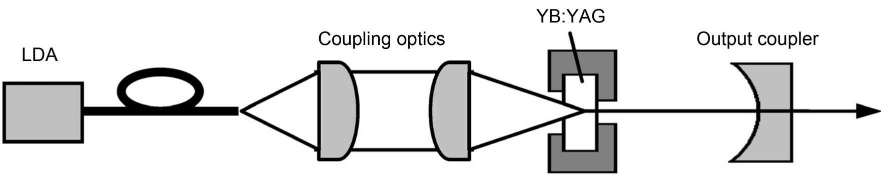

Fig. 3. Schematic diagram of the LDA pumped Yb:YAG 1030 nm laser.

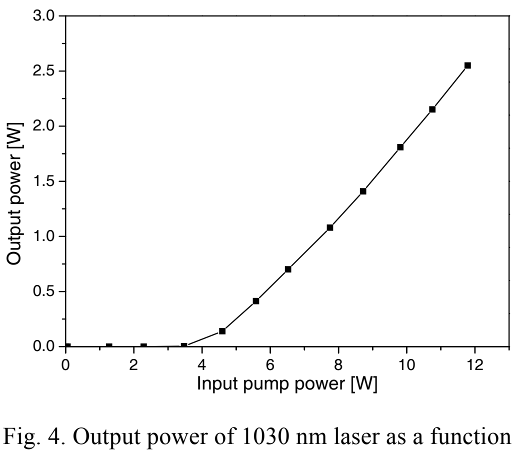

Fig. 4. Output power of 1030 nm laser as a function of input pump power.

In the experiment, the rear surface of Yb:YAG has no high reflective coating for 940 nm, so the pump light cannot realize second pump. If it was high reflectivity coated, the laser efficiency will be improved.

4. Conclusions

In summary, a LDA end-pumped Yb:YAG 1030 nm laser has been investigated. The maximum output power was 2.55 W with the input pump power of 11.79 W. The optical conversion efficiency was 21.7%.

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References

[1] JUN DONG, *Numerical modeling of CW-pumped repetitively passively Q-switched Yb:YAG lasers with Cr:YAG as saturable absorber*, Optics Communications **226**(1–6), 2003, pp. 337–344.
[2] HONEA E.C., BEACH R.J., MITCHELL S.C., SKIDMORE J.A., EMANUEL M.A., SUTTON S.B., PAYNE S.A., AVIZONIS P.V., MONROE R.S., HARRIS D.G., *High-power dual-rod Yb:YAG laser*, Optics Letters **25**(11), 2000, pp. 805–807.
[3] QIANG LIU, MALI GONG, FUYUAN LU, WUPENG GONG, CHEN LI, DONGDONG MA, *Corner-pumped Yb: yttrium aluminum garnet slab laser emitted up to 1 kW*, Applied Physics Letters **88**(10), 2006, p. 101113.
[4] VOSS A., BRAUCH U., WITTIG K., GIESEN A., *Efficient high-power-diode-pumped thin-disk Yb:YAG-laser*, Proceedings of SPIE **2426**, 1994, pp. 501–508.
[5] HUEGEL H., BOHN W.L., *Solid state thin disk laser*, Proceedings of SPIE **3574**, 1998, pp. 15–28.
[6] YANG H., KAWATA S., KOBAYASHI T., *Performance characteristics of diode-pumped miniature Yb:YAG laser*, Proceedings of SPIE **4595**, 2001, pp. 22–29.
[7] KOECHNER W., *Solid-State Laser Engneering*, 6th Edition, Springer Press, New York, 2006, p. 478.

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