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340 W Nd:YVO_4 Innoslab laser oscillator with direct pumping into the lasing level

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Abstract

We present a high power 340 W Nd:YVO_4 Innoslab laser end-pumped by 880 nm laser-diode stacks. A maximum output power of 340 W was obtained at the absorbed power of 710 W with optical conversion efficiency up to 47.9 %. At the output power of 300 W, the M^2 factors in the unstable direction and the stable direction were 2.1 and 3.4, respectively.

Keywords: laser diode stack, 1064 nm, dual-end-pumped, Nd:YVO_4, innoslabm

(Some figures may appear in colour only in the online journal)

1. Introduction

In diode-pumped solid-state lasers, thermal load may cause serious thermal aberrations and thermally induced fracture in the lasing material. In many cases, decreasing the quantum defect is a cost-effective way to lessen the thermal effect in the lasing material. Compared with neodymium doped lasers pumped by an 808 nm laser diode, lasers pumped by an 880 nm laser diode can reduce the quantum defect by 30%. In recent years, many studies have been conducted with direct pumping into upper lasing levels [1–7].

Combining high overlapping efficiency with outstanding cooling effect, partial-end pumping with stable–unstable hybrid resonator lasers (Innoslab) has been proven to be appropriate for power scaling with high beam quality and high efficiency [8–12].

For dual-end-pumped geometry, the thermal gradient is smaller and the thermal focal length is longer compared with single-end-pump geometry under the same pump power. Therefore, dual-end-pump geometry adopted for higher power pump can produce higher output power [13, 14]. In this letter, we present a dual-end-pumped Nd:YVO_4 Innoslab laser with direct pumping to the lasing level.

2. Experimental setup

The experimental setup is shown in figure 1. The main structure was comprised of two laser-diode stacks (Jenoptik), two coupling systems and a folded cavity. Each of the two laser-diode stacks was arranged in a water-cooled heat sink with a central wavelength around 880 nm by fixing the temperature of the cooling water. Each bar was collimated by an individual cylindrical micro lens in the vertical direction. The heat sinks of the two laser diodes and the crystal were cooled by circulating water at the same temperature. Each coupling system consisted of four cylindrical lenses, a planar waveguide and a group of spherical lenses. The pumping light was delivered into the laser medium and shaped rectangularly on each end of the crystal slab. The rectangular cross section measured 14 mm × 0.4 mm in horizontal length and vertical width, respectively. The delivery efficiency of the pump systems was about 90%.

As displayed in figure 1, the folded stable–unstable hybrid resonator was located between the two coupling systems. The resonator consisted of mirror M1, mirror M2 and mirror M3. M1 was a 500 mm-radius-curvature concave spherical mirror that was high-reflection (HR) coated at 1064 nm and high-transmission (HT) coated at 880 nm. M2 was a -350 mm-radius-curvature convex cylindrical mirror that was high-reflection (HR) coated at 1064 nm. M3 was a flat mirror that was 45° high-reflection (HR) coated at 1064 nm and high-transmission (HT) coated at 880 nm. The folded resonator was an off-axis positive confocal unstable resonator in the horizontal direction and a stable resonator in the vertical direction. The cavity was about 75 mm

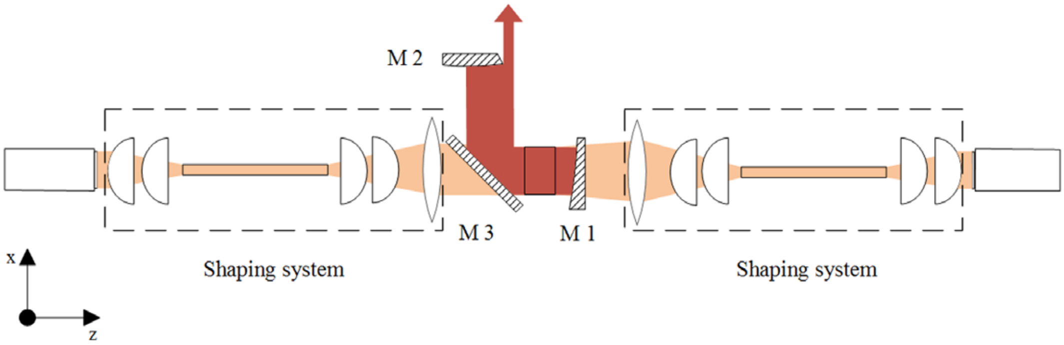

Figure 1. Scheme of the experimental arrangement.

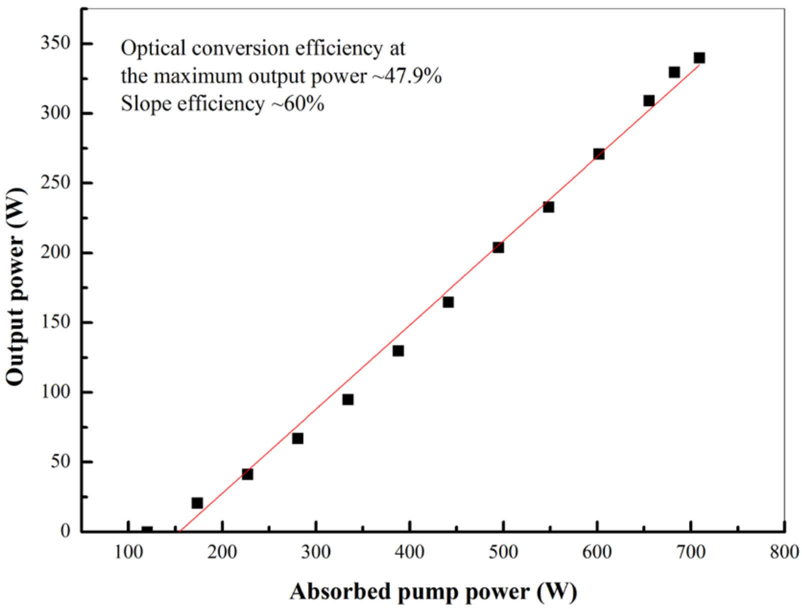

Figure 2. Plot of the output power as a function of absorbed pump power.

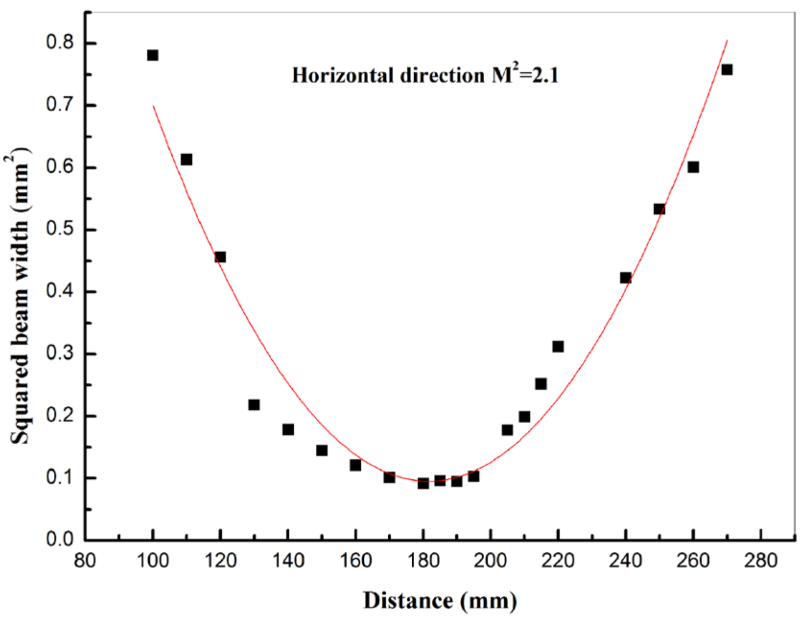

Figure 3. The squared widths of the beam profile at different positions in the unstable direction and the fitting result.

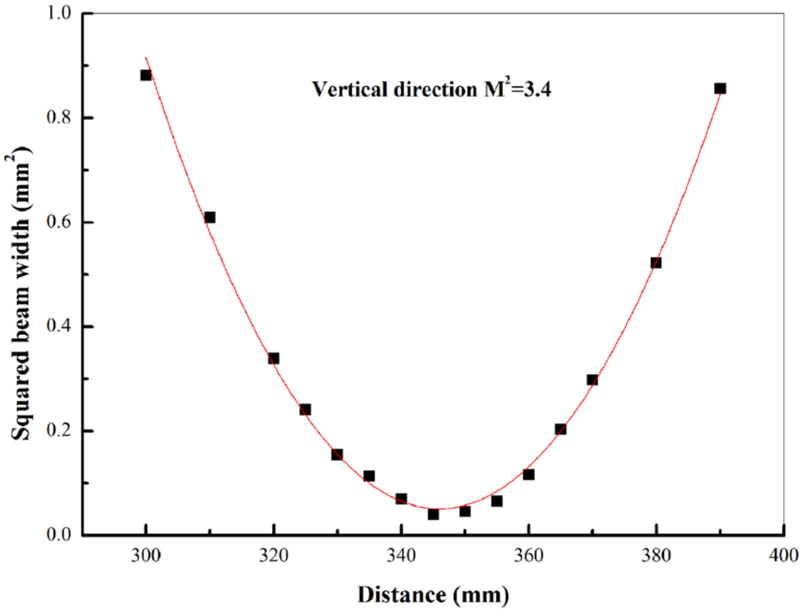

Figure 4. The squared widths of the beam profile at different positions in the stable direction and the fitting result.

in length. The laser was coupled out at the polished edge of M2. The magnification in the horizontal direction was M = −R1/R2 and the equivalent transmission was determined by the equation T = 1–1/M = 30%. The $Nd:YVO_4$ crystal, which had a 0.3 at.% Nd-ion concentration, measured 14 mm × 1 mm ×12 mm. The a-cut laser crystal fixed close to M1 was wrapped with indium foil and mounted in two water-cooled heat sinks with two large faces 14 mm × 12 mm. The c axis was along the 14 mm face. Both end faces 14 mm × 1 mm were both polished and high-transmission (HT) coated at 1064 nm and 880 nm.

3. Results and discussion

Figure 2 shows the output power as a function of the absorbed pump power. An output power of 340 W at the absorbed pump power of 710 W with optical conversion efficiency of 47.9 % was achieved. The slope efficiency was around 60%. To the best of our knowledge, these are the best results achieved for a CW laser in a diode-end-pumped $Nd:YVO_4$ geometry oscillator without a laser power amplifier.

The M^2 factors were measured at the output power of 300 W. A CCD camera was used to measure the laser spot widths at different positions behind an f = 350 mm lens. The M^2 can be defined by the formula

$$d(z)^2 = d_0^2\left(1 + \left(4\lambda M^2 z / \left(\pi d_0^2\right)\right)^2\right)$$

where $d(z)$ is the beam diameter at z position, d_0 is the beam diameter at laser waist position, λ is the laser wavelength and z is the distance to the artificial waist position. According to the formula, the squared beam diameters at different positions were fitted. The results are shown in figures 3 and 4. The M^2 factors were 2.1 and 3.4 in the unstable direction and the stable direction, respectively.

4. Conclusions

In summary, we demonstrated a high power dual-end-pumped $Nd:YVO_4$ 1064 nm slab laser with a stable–unstable hybrid resonator. As much as 340 W output power was achieved at the absorbed pump power of 710 W with optical conversion efficiency of up to 47.9%. At the output power of 300 W, the M^2 factors in the unstable direction and the stable direction were 2.1 and 3.4, respectively.

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