22 watt, diode side-pumped Nd:YVO_4 laser with 63% optical-to-optical efficiency

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Abstract

We demonstrate 63% optical-to-optical conversion efficiency and 22 W of multi-mode output power in a compact, 8 cm long Nd:YVO_4 oscillator. The slope efficiency of 74% is to our knowledge the highest so far reported.

Introduction

Diode pumped solid state laser are developing at a very fast rate mainly because of decreasing cost of diode lasers and increasing power, narrower spectral emission and better beam quality of the diodes. At the same time, materials that in some aspects have better characteristics than Nd:YAG are on the market such as Nd:YVO_4, Nd:$GdVO_4$, Yb:YAG and others. Resonator geometries for diode-pumped solid-state laser have changed quite a bit from the traditional rod geometry to currently favored face-pumped thin-disk lasers and fiber lasers. Within the existing variety of geometries and gain materials there is one combination that is particularly interesting because of its reduced complexity and high efficiency: the edge-pumped slab-laser using grazing-incidence geometry and a gain media with a very high pump absorption cross-section. This geometry is power scalable, very compact and the one-dimensional heat removal of the planar slab resolves thermally-induced depolarization.

Damzen et al.[1] demonstrated high efficiency and good beam quality with Nd:YVO_4 using a grazing incidence configuration inside the gain media. In this case, the intracavity beam bounces of the crystal surface at the exact face that is being pumped by the diode laser. Therefore, good overlap between pump beam and intracavity beam is guaranteed. Furthermore, YVO_4 is birefringent and therefore thermally induced birefringence does not impact on the performance of the high power Nd:YVO_4 laser [2].

In this work, we describe a compact cavity with less than 8 cm overall length, showing very high conversion efficiency and slope efficiency in multimode operation and 22 W of output power.

Experimental Setup

The laser crystal is a Nd:YVO_4 with 1.1 at.% neodymium doping with dimensions 22×5×2 mm^3.

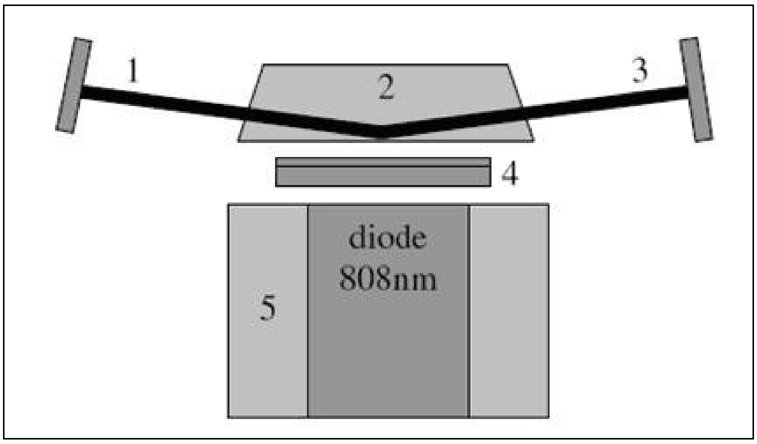

Figure 1: Cavity configuration: 1) end mirror (R=50cm); 2) Nd:YVO_4 crystal; 3) plane output mirror with 36% transmission; 4) 6.4mm cylindrical lens; 5)40 W, TM-polarized diode bar.

The edge faces are angled at 5º to minimize parasitic self-lasing effects inside the gain media and have AR coating for the 1064 nm laser wavelength. The c-axis orientation is perpendicular to the large surfaces used for heat removal. The crystal is pumped on the 22mm × 5mm edge face, which has AR coating for the 808 nm wavelength.

The pump source is a 40 watts TM-polarized diode bar (Coherent Inc.) operating at 808 nm. The TM polarization is parallel to the c-axis of the crystal and hence accesses the high absorption coefficient of 31.4 cm^{-1} [3]. The pump radiation is focused into the crystal with a 6.4 mm focal cylindrical lens generating a line focus of 60 µm diameter. The crystal is mounted inside a copper block and good refrigeration is guaranteed using 1 mm indium foil between crystal and copper. The temperature of the diode is fixed at 29 ◦C with a thermoelectric cooler in order to obtain the diode emission at 808 nm. A re-circulating chiller is used for heat removal from the crystal and the diode.

The cavity comprises two mirrors, one high reflector of 50 cm radius of curvature and a flat mirror with 36% transmission. The total internal reflection at the pump face has an angle of approximately 5º (85º with the normal of the pump face). The scheme is shown in figure 1. The distance between the center of the crystal and the mirrors is less than 4 cm. Power input and output measurements were done with a, calibrated power meter.

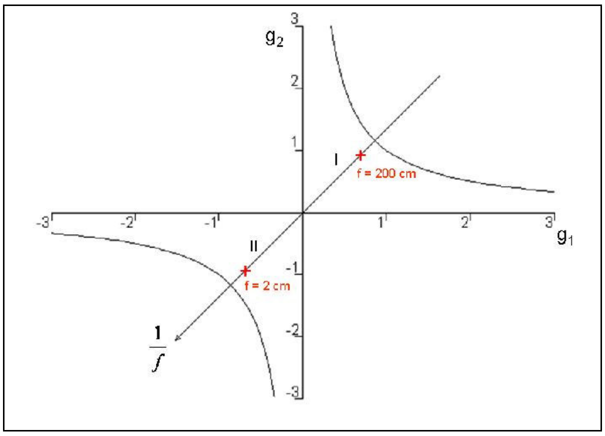

Figure 2: Stability diagram and zones (I and II). 1/f is the dioptric power of the thermal lens.

Figure 2 shows the stability diagram and the dioptric power of thermal lens for our resonator. Because this resonator has joint stability zones [4], it is stable for a very large range of thermal lenses, even in the presence of a large TEM_{00} mode inside the crystal.

Results and Discussions

Figure 2 shows the output power of the laser versus the diode pump power.

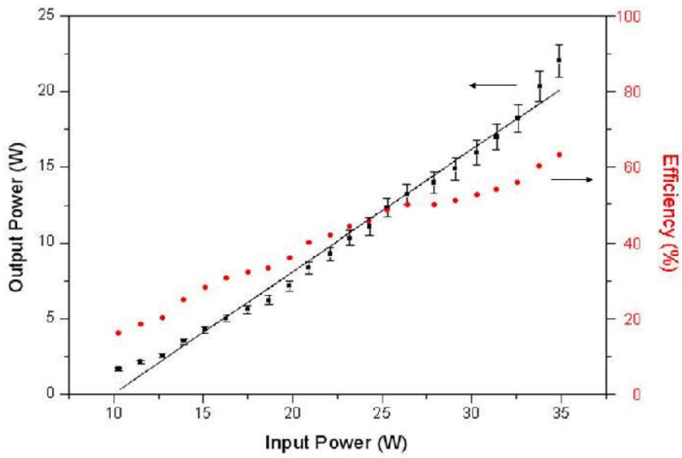

Figure 3: Output power versus diode pump power (■) and efficiency versus pump power (●).

We achieve 22.0 watts of multimode output for a pump power of 34.9 watts, corresponding to an optical-to- optical conversion efficiency of 63% and a slope efficiency of 74%. This is the highest slope efficiency reported so far for an output power above 20 W and near the theoretical limit of 76% due to the ratio of lasing to pump photon energies [1].

Conclusions

In this work, we demonstrate 22 W of multimode output power, a high optical-to-optical conversion efficiency of 63% and a slope efficiency of 74% with a very compact and simple Nd:YVO_4 cavity that uses joint stability zones.

Acknowledgements

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References

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