Comparison of grazing incidence Nd:YVO_4 lasers pumped at 808 and 880 nm

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Abstract: We compare, for the first time to the best of our knowledge, the behavior of a grazing incidence Nd:YVO_4 laser when pumped at 808 nm and when directly pumped at 880 nm. We report a more linear behavior of the output power as a function of input power under direct pumping, due to a decrease in thermal effects.

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1. Introduction

The Nd:YVO_4 crystal is currently one of the most efficient materials for diode pumped solid state lasers. It has a tetragonal structure, and the laser emission is π polarized (parallel to the crystal c-axis), with a stimulated emission cross section of (22 ±3) x 10^{-19}cm² at 1064 nm [4]. It is naturally birefringent and thus thermally induced birefringence does not impact on the performance of the high power Nd:YVO4 laser [2]. At 808 nm, this material has an absorption coeficient of 40 cm^{-1} in π and ~8cm^{-1} in $\sigma$and at 880 nm ~30 cm^{-1} in π and ~2 cm^{-1} in σ.

The side-pumping configuration with a grazing incidence inside the Nd:YVO_4 crystal has been first demonstrated, with high efficiency and good beam quality, by Damzen et al [5]. With this configuration the intracavity beam bounces of the crystal's pump surface, therefore, generating a good overlap between pump beam and intracavity beam, making this geometry particularly interesting [1]

Direct pumping to the upper laser level should be the more efficient scheme for this four level laser, when compared to pumping at 808 nm, because it eliminates part of the quantum efficiency loss [6]. When the system is pumped at the traditional 808 nm, the atom is excited from the fundamental $^4I_{9/2}$ level to the $^4F_{5/2}$ level and by a non radiative transition decays to the upper laser level $^4F_{3/2}$ from where it decays radiatively to the fundamental Stark Level of the $^4I_{11/2}$ level, as in Fig. (1). Pumping the system with 880 nm the atom is excited directly to the $^4F_{3/2}$ level, reducing the Stokes shift between the pump and the laser photon, and heat reduction of ~25% [7] has been demonstrated.

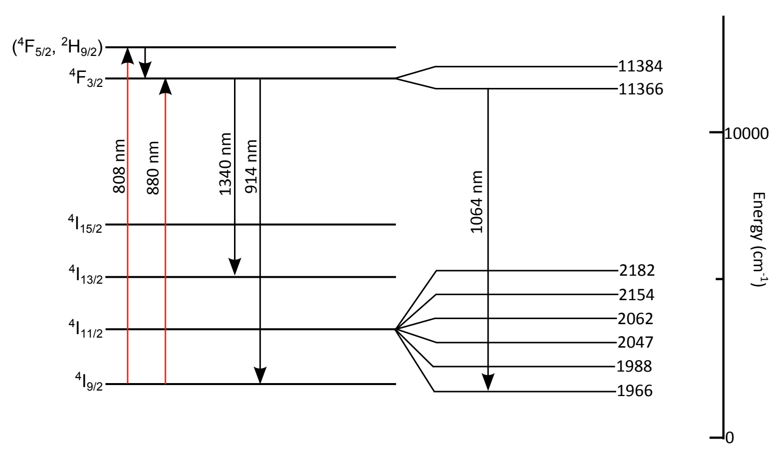

Fig. 1. Energy level diagram of Nd:YVO_4. The energies of the Stark Levels are shown for $^4I_{11/2}$ and $^4F_{3/2}$. [8]

2. Materials and Methods

The laser material used in our experiments was a Nd:YVO_4 crystal doped with 1.1 at. % of dimensions 22x5x2 mm³, with the c axis orientation perpendicular to the larger surfaces. The 5x2 mm faces were cut with an angle of 5° to minimize possible parasitic self-lasing effects and was antireflection coated for 1064 nm. The 22x5 mm surface, which was the pumped surface, was coated for high transmission at 808 nm. The crystal was mounted on a copper holder which was refrigerated with the use of a re-circulating chiller, and a 1 mm indium foil was placed between the crystal and the holder in order to facilitate the heat exchange.

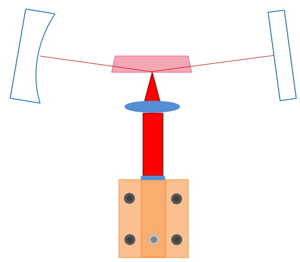

Fig. 2. Schematic of the pumping scheme

For the pumping source, we used two different diode lasers, one of them operating at 808 nm, and the other at 880 nm. The first one is a 40 watts TM-polarized diode bar (Coherent Inc.), and the other a 70 watts TE-Polarized diode bar (Jenoptiks); with the latter we used a zero order half wave plate (Ealing) to rotate the polarization, and hence access the higher absorption coefficient of the crystal in the π polarization direction. Both diode lasers were mounted on a copper plate, with an indium foil in between, and had their temperature controlled by a Peltier element. In order to focus the pump beam into the crystal we used a 6.4 mm focal cylindrical lens generating a line focus of 60 μm diameter.

The cavity was 7 cm long, comprising two mirrors, one high reflector of 50 cm radius of curvature and a flat output coupler with 30% transmission at 1064 nm, as shown in Fig.(2)

3. Results and discussions

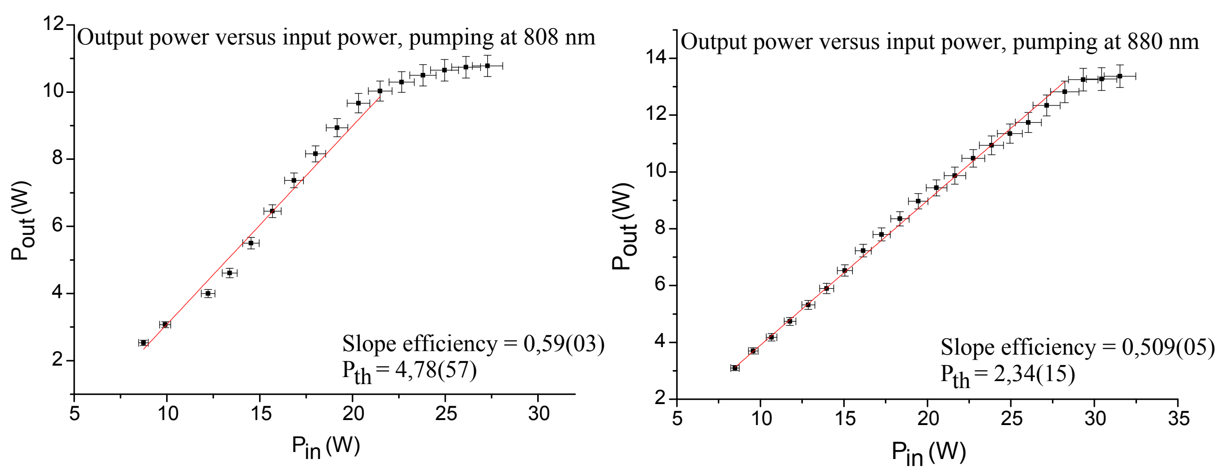

Fig. 3. Graphics of output power versus input power, for pumping at 808 nm and 880 nm diodes, with a linear fitting

Analizing the graphics shown in Fig. (3), it is evident that direct pumping decreases the “roll over” behavior that appears under 808 nm pumping, which is due to the decrease of the thermal lens. A linear fit is shown in each graphic, for which we did not considered the points that do not behave linearly. For the 808 nm pumping we achieved a slope efficiency of 59%, threshold power of 4,78 W and optical-to-optical conversion efficiency of 47%. For the 880 nm pumping, the slope efficiency was 51%, threshold power 2,34 W and optical-to-optical conversion efficiency of 45%. Although the slope efficiency was slightly better for the indirect pumping, the threshold power was approximately twice the value obtained under direct pumping, which shows clearly less losses with the direct pumping situation.

4. Conclusions

Comparing the behavior of the system, when pumped at 808 nm and direcly pumped at 880 nm, a reduction of the threshold power, higher output power and less roll over was shown under direct pumping. We intent to perform a double bounce configuration in order to study fundamental mode TEM_{00}operation when the system is directly pumped.

References

1. F. Camargo, "22 watt, diode side-pumped Nd:YVO_4 laser with 63% optical-to-optical efficiency", Annals of optics (2006). 1
2. A. Minassian, B. Thompson, M. J. Damzen, "High power TEM00 grazing-incidence Nd:YVO4 oscillators in single and multiple bounce configurations", Opt. Comm. **245**, 295-300 (2005). 1
3. Z. Chen, X. Yan, X. Jiang, Q. Li, "The thermal effect in a grazing-incidence slab laser with the novel composite cooling method", Optical and Quantum Electronics **41,** 27-38 (2009)
4. http://www.coherent.com/downloads/NdYVO4_DS.pdf, acessed in june 21^{th}, 2013. 1
5. M. J. Damzen, M. Trew, E. Rosas, G. J. Crofts, "Continuous-wave Nd:YVO4 grazing-incidence laser with 22.5 W output power and 64% conversion efficiency", Opt. Comm. **196**, 237-241 (2001). 1
6. R. Lavi, S. Jackel, Y. Tzuk, M. Winik, E. Lebiush, I. Paiss, " High-efficiency diode direct-pumping of Nd:YVO_4 grazing incidence oscillators", Lasers and Electro-Optics Europe (2000) 1
7. R. Lavi, S. Goldring , "Heat generation following direct pumping of Nd:YVO4 with and in the absence of stimulated emission" Conference Paper ASSP (2006) 1
8. The energy level diagram was elaborated based on the values on the following reference: A. A. Kaminskii, "Crystalline Lasers: Prysical processes and Operating Schemes" (CRC Press, Inc., 1996), pp. 137. 1

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