High Average Power, High Repetition Rate Side-Pumped Nd:YVO_4 Slab Laser

Kevin J. Snell and Dicky Lee
Q-Peak Incorporated
135 South Rd., Bedford, MA 01730
(781) 275-9535 FAX (781) 275-9726
e-mail: ksnell@qpeak.com, dlee@qpeak.com

ABSTRACT

We discuss an efficient, side-pumped Nd:YVO_4 slab laser using two 20 W diode laser bars with a CW output power greater than 15 W, a slope efficiency of 51.6% and an overall efficiency of 40%. In Q-switched operation, over 11 W of output power was achieved at a repetition rate of 50 kHz in a single transverse mode, near-diffraction limited beam with pulse widths less than 12 ns.

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We discuss an efficient, side-pumped Nd:YVO_4 multi-pass slab laser using two 20 W diode laser bars with a CW output power greater than 15 W, a slope efficiency of 51.6% and an overall efficiency of 40%. In Q-switched operation, over 11 W of output power was achieved at a repetition rate of 50 kHz in a single transverse mode, near-diffraction limited beam with pulse widths less than 12 ns. Operating on the 1342 nm transition, the laser has produced a multimode output greater than 9 W with a slope efficiency of 36% and 6 W with 26% slope efficiency in single-transverse mode operation. We have also operated the multi-pass slab as an amplifier with a power extraction of 11 W and a small-signal gain greater than 17.

1. INTRODUCTION

There are many applications for high-repetition rate (>20 kHz) Q-switched lasers with high average power (>10 W) that can be frequency-converted using non-linear optics. Some examples are Mid-IR remote-sensing, visible display applications, and UV materials-processing applications. In order to achieve efficient non-linear frequency conversion, excellent beam quality and high peak powers are required. However, the short pulses required for high peak power are difficult to achieve in laser materials such as Nd:YAG and Nd:YLF. One material which offers the possibility of achieving high peak power at high pulse rates is Nd:YVO_4, due to its higher emission cross-section and shorter fluorescence lifetime.

Moderate average powers (≈5 W) with high beam quality have been demonstrated in Nd:YVO_4 using end-pumping. However, it is difficult to scale average power much beyond this level without compromising beam quality, peak power, or increasing system complexity. Work at Light Solutions Inc. [1] has demonstrated a 9 W average power, Q-switched, end-pumped laser using a beam shaper to obtain a high brightness diode pump source. Diffusion-bonded undoped YVO_4 end caps were required to prevent thermal fracture of the Nd:YVO_4 crystal. Use of a beam shaper and diffusion-bonded crystals in this design has significantly increased the cost and complexity of the system. High CW powers have been obtained by Spectra Physics using fiber-coupled bars [2]; however this technology requires large spot sizes to avoid thermally-induced aberrations and crystal fracture. In order to efficiently extract power in the fundamental mode, a large beam waist is required which leads to a longer resonator. The larger pump spot size leads to lower gain and a longer cavity results in a longer cavity photon lifetime. Both of these factors lead to longer Q-switched pulses, which reduce the peak-power potential of the laser.

A simpler means of scaling diode-pumped solid-state lasers is to use side-pumping. However, in side-pumped lasers it can be difficult to achieve efficient extraction in a near-diffraction limited beam. Furthermore, side-pumping often results in lower inversion densities and hence less gain. In this work, we present results of a highly efficient, side-pumped Nd:YVO_4 laser that has very high-gain for short-pulse generation at high repetition rates.

2. EXPERIMENTAL WORK

The high-power side-pumped slab laser is shown schematically in Figure 1. It consists of an a-axis cut Nd:YVO_4 slab, side-pumped by two collimated 20 W diode laser bars emitting around 808 nm. A proprietary multi-pass resonator is used increase the effective crystal length and efficiently extract the available inversion in a low-order-transverse-mode beam. A 50 cm radius plano-concave high reflector is used for multi-transverse mode operation and a 51 cm cylindrical convex high reflector is used for single mode operation. A plane-plane, 50% transmission output coupler is used for both resonator configurations. Q-switched operation is obtained using an acousto-optic modulator for repetition rates greater than 25 kHz and a BBO Pockels' cell for repetition rates less than 25 kHz.

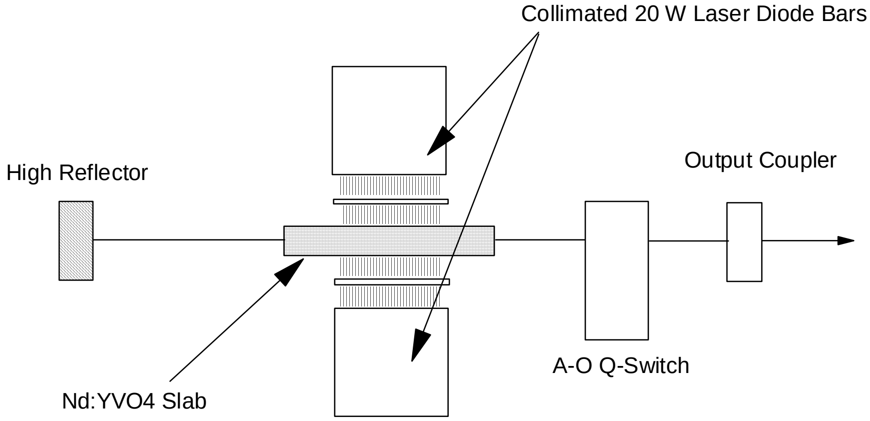

Figure 1. Schematic of the side-pumped Nd:YVO_4 laser.

A plot of 1064 nm laser output power as a function of incident diode pump power is shown in Figure 2 for both multi- and single-transverse-mode, continuous-wave (CW) operation. In multimode operation, the maximum output power obtained was 15.1 W for a pump power of 37.2 W, corresponding to an optical efficiency of 40.6%. The slope efficiency, measured by a least squares fit to data, was 51.6% and the threshold pump power was 9 W. In single transverse mode (TEM_{00}) operation, the maximum output power obtained was 13 W at a pump power of 37.2 W with a slope efficiency of 46.2% and an optical efficiency of 35.2%. Pump electrical power consumption was 100 W resulting in an electrical-optical (wall-plug) efficiency of 15% for multimode operation and 13% for TEM_{00} mode operation. We measured the second moment beam quality factor, M^2 using a Coherent Modemaster to be less than 1.2 in the horizontal plane and less than 1.1 in the vertical plane.

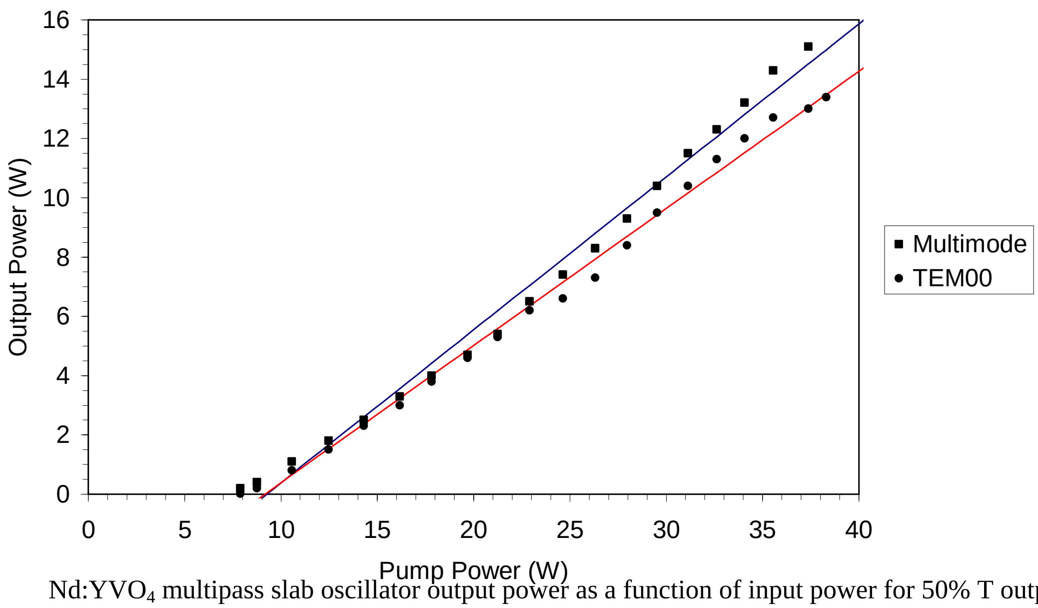

Figure 2. Nd:YVO_4 multipass slab oscillator output power as a function of input power for 50% T output coupler.

Figure 3 summarizes the Q-switched performance of the Nd:YVO_4 slab laser. Using an A-O modulator, we Q-switched the laser at repetition rates from 40-100 kHz. For a repetition rate of 40 kHz, the average output power was 10.5 W, corresponding to a pulse energy of 0.26 mJ. The pulse width at this rate was 9 ns, resulting in a peak power of 29 kW. At a repetition rate of 100 kHz, the average power was 13.6 W with a pulse width of 16 ns which corresponds to a peak power of 8.5 kW. Using an electro-optic Q-Switch at a repetition rate of 20 kHz, we obtained an average power of 8.2 W (0.41 mJ/pulse) with a pulse width of 7.7 ns, producing a peak power of 53 kW.

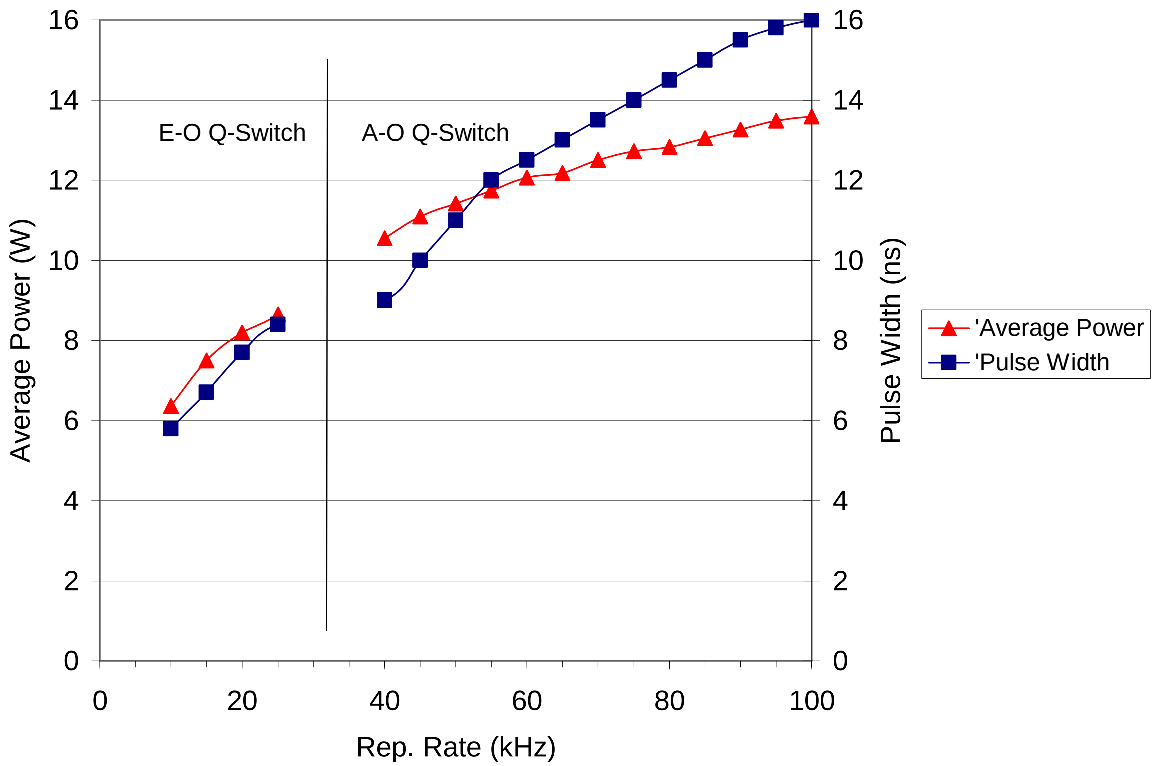

Figure 3. Q-Switched performance of the $Nd:YVO_4$ multi-pass slab laser.

3. 1342 nm LASER PERFORMANCE

The $Nd:YVO_4$ multi-pass slab has also been operated as an oscillator at 1342 nm. In this case, the slab was coated with dual-band AR coatings for 1064 and 1342 nm. with CW multi-mode output powers greater than 9 W and single-transverse-mode output power greater than 6 W. In 1342 nm Q-switched operation, pulse width of less than 60 ns have been obtained at a repetition rate of 50 kHz. At the conference,we will present further details of the 1342 nm laser and power scaling using amplifier modules.

4. SLAB AMPLIFIER PERFORMANCE

5. CONCLUSIONS

We have described an efficient, side-pumped, high-gain $Nd:YVO_4$ laser that produces short Q-switched pulses at high repetition rates. A CW multimode output power greater than 15 W was obtained with an optical efficiency of 40%. In single transverse mode operation, the output power was greater than 13 W in a near-diffraction limited (M^2<1.2) beam. Q-switched operation has resulted in pulsewidths ranging from 6-16 ns for repetition rates from 10-100 kHz and peak powers ranging from 8.5 kW to greater than 100 kW. This high peak power, high brightness laser source will be ideal for frequency conversion to other wavelengths using non-linear optical materials.

4. REFERENCES

1. M. Fuller, D. Matthews, L.R. Marshall, Conference on Lasers and Electro-Optics 1998, Paper CThP1
2. W.L. Nighan, D. Dudley, M. S. Keirstead, Conference on Lasers and Electro-Optics 1995, Paper CMD5