Passive Q-switching of a diode side-pumped $Nd:YVO_4$ laser

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Abstract

We demonstrate a qcw side pumped $Nd:YVO_4$ with a high power output. Passive Q-switching was tried with different saturable absorber, Cr^{4+}:YAG and LiF:F^{2-} . Complete modulation and 9,8ns q-switched pulse duration was obtain with a LiF:F^{2-}.

Introduction

Passive Q-switched laser has some advantages in terms of price, simplicity and compactness, which are very interesting for many applications such as remote sensing and medicine. There are many saturable absorbers used to achieve passive Q-switching operation, for example, dye solutions, color center crystals such as LiF:F^{2-} [1] and Cr^{4+}:YAG [2]. Cr^{4+}:YAG has been successfully used as passive q-switch for many gain media. However, it is usually difficult to operate this saturable absorber in conjunction with the $Nd:YVO_4$ laser because of the large gain of YVO_4. On the other hand, the LiF has a lower price, a high damage threshold (over 40GW/cm^2), is very hard and easy to produce and polish [1]. The F^{2-} centers are very stable at room temperature.

Laser materials with long upper state lifetime, like Nd:YAG and Nd:YLF, are common used in q-switched lasers. In recent years other crystals have been used as $Nd:GdVO_4$ and $Nd:YVO_4$. $Nd:YVO_4$ is a high gain crystal with a high emission cross section and short fluorescence lifetime. This crystal is very hard and can be pumped with high power but it produces a strong thermal lens that creates problems with stability and high power [3]. On the other hand, very high pulse repetition rates have been demonstrated using vanadate crystals.

In this work we describe a pulsed, qcw high power $Nd:YVO_4$ and a passively Q-switched laser with very short pulse width.

Experimental Setup

The laser crystal is a $Nd:YVO_4$ with 1.1 at.% neodymium doping with dimensions 22 × 5 × 2 mm^3 (Casix Inc.). The end faces (5 × 2 mm^2) have AR coating for the 1064 nm laser wavelength and are angled at 5º to minimize parasitic self-lasing effects inside the gain. The crystal is pumped on the 22mm × 5mm edge face, which has AR coating for the 808 nm wavelength. The c-axis orientation is perpendicular to the large surfaces used for heat removal. The crystal is mounted inside a copper block and good refrigeration is guaranteed using 1 mm indium foil between crystal and copper. A re-circulating chiller is used for heat removal from the crystal and the diode.

The pump source is a 100 watts TM-polarized diode bar (Coherent Inc.) operating at 806 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} [4]. The diode bar was operated in pulsed mode to minimize problems and instability provide by the thermal lens that is very strong in $Nd:YVO_4$. In this regime we can pump the crystal with high power without loss of efficiency and stability before observed its behavior in the cw regime.

The cavity comprised two mirrors, one high reflector of 20 cm radius of curvature and a flat mirror with 50% transmission. The total internal reflection at the pump face had an angle of approximately 5º. A 6.4 mm cylindrical lens was used in front of the diode bar in order to focus the pump radiation into the crystal, generating a line focus of 60 μm in the vertical direction.

To passively q-switch the laser, we tested two saturable absorbers, Cr^{4+}:YAG and LiF:F^{2-}. To use these crystals, an intracavity aperture was introduced, between the crystal and the rear mirror, to improve beam quality but it reduced the output power in almost 50%. In the first experiment, we used a Cr^{4+}:YAG as saturable absorber with 55%, 70%, 80% and 90% transmission in 1064nm. Nevertheless, these crystal did not work as expected, so we used in a second step a 3 cm longer LiF:F^{2-} crystal with transmission of less than 40% and an anti-reflection coating on one polished side. These crystals were introduced between the slit and the $Nd:YVO_4$ crystal, Figure 1. The Q-switched pulse width was measured with a 200 MHz oscilloscope.

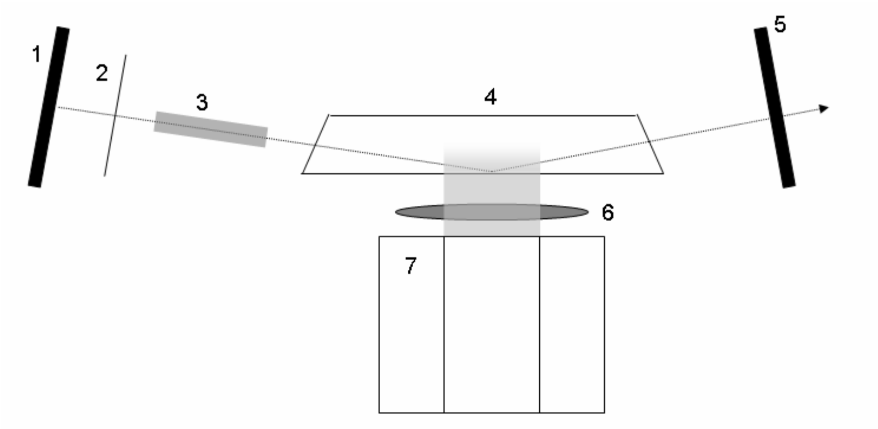

Figure 1: Cavity configuration: 1) rear mirror (R=20cm), 2) intracavity slit, 3) saturable absorber, 4) Nd:YVO_4 crystal, 5) plane output coupler, 6) 6,4 mm cylindrical lens and 7) 806 nm diode.

Results and Discussions

Without the saturable absorber we achieved 36,8 watts of multimode output for a pump power of 100 watts with a slope efficiency of 50%, Figure 2. With the introduction of the intracavity slit the output power was reduced to 21 watts with an improvement in beam quality (approximately M^2 of 3). The output power and efficiency are lower because the emission of the diode was 803nm when operated at 35ºC. This emission is not centered at the absorption peak of Nd:YVO_4 (808nm).

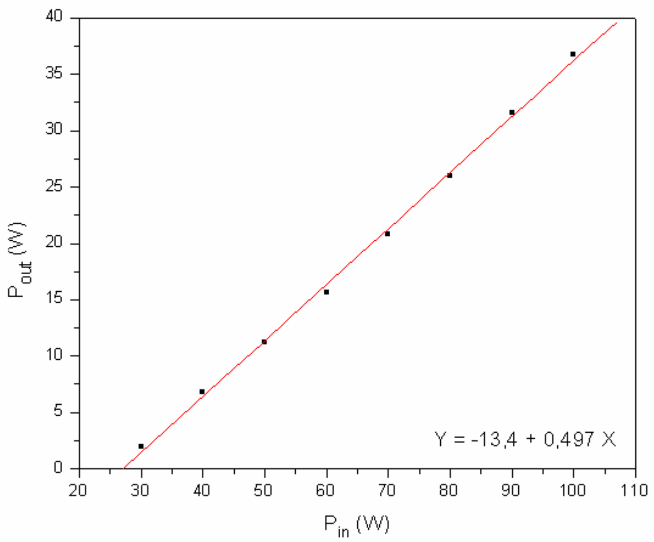

Figure 3: Output power versus diode pump power without an intracavity slit.

With Cr^{4+}:YAG as absorber, the laser was not totally modulated, showing that the transmission of the saturable absorber has to be lower than 55%. Even stacking the Cr^{4+}:YAG absorbers did not help, giving still a residual qcw background in the temporal behavior of the laser. With the LiF:F^{2-} we observed a 100% modulation depth with very short q-switched laser pulses having a FWHM pulse width of 9,8ns, Figure 3. This pulse is one of the many pulses formed inside the qcw pulse (50 microsecond duration) of the diode. Single q-switched pulse regime could not be achieved due to limitations of our diode power supplies; the smallest pulse had 50µs duration.

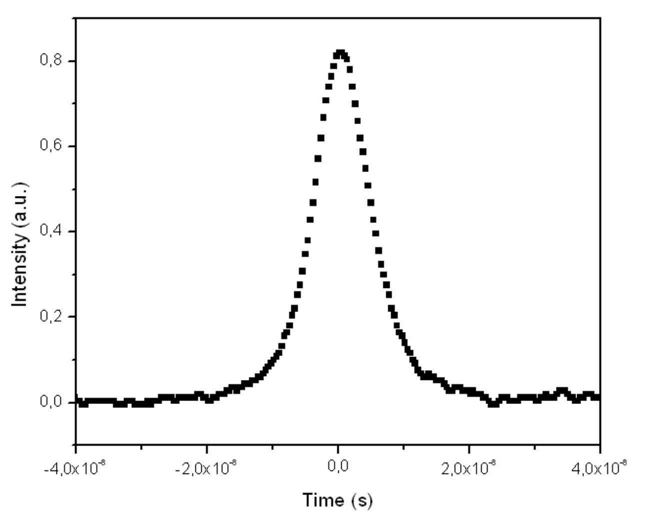

Figure 3: Temporal profile of q-switched laser pulse with a FWHM pulse width of 9,8ns.

Conclusions

In this work, we demonstrated a side pumped qcw Nd:YVO_4 generating 36,8 watts of output power for a pump power of 100 watts. The qcw, high pump power regime does not show the thermal problems noticed during cw operation. This laser was passively Q-switched with different saturable absorbers, specifically Cr^{4+}:YAG and LiF:F^{2-}. Complete modulation with a 9,8ns q-switched pulse was obtained only with LiF:F^{2-}.

Acknowledgements

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