LD-side-pumped Nd:YVO_4 self-Raman laser at 1176 nm

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Abstract: We demonstrate a diode-side-pumped Nd:YVO_4 self-Raman laser at 1176 nm in a grazing incidence configuration operating in quasi-continuous mode. More than 8 W of output power was achieved in multimode operation, corresponding to a slope efficiency of 15%. With TEM_{00} mode operation is also demonstrated.

OCIS codes: (140.0140) Lasers and laser optics; (140.3530) Lasers, neodymium; (140.3550) Lasers, Raman

1. Introduction

In the past decade, there has been great interest in the development of solid state Raman lasers, because they provide a practical way for extending the fundamental wavelengths into several longer ones, depending on how many resonant Raman frequencies can be accessed by the laser resonator. Applying second harmonic and sum-frequency generation to these emissions, as many as ten different frequencies can be obtained in the visible range at otherwise hard to reach wavelength. The most compact, simple and low-cost Raman lasers are the self-Raman lasers, in which laser generation and stimulated Raman scattering (SRS) processes occur in the same crystal presenting lower resonator losses because of less optical components.

In the traditional diode-end-pumped configuration, it is hard to achieve high powers because of strong thermal lensing and lack of power scalability (pumping can only occur from the two ends) [1]. An attractive configuration is a side-pumping scheme with a bounce geometry [2] and, for the Nd:YVO_4 laser, this geometry has shown high output powers and a slope efficiency of 74% [3] at 1064 nm. Until today, every work with Raman lasers using side-pumping has used a q-switching device to generate high enough peak powers inside the crystal given the low Raman gain [4][5][6]. In this work we investigate for the first time intracavity SRS laser operation in a side-pumped, grazing incidence configuration.

2. Laser experimental setup

Fig. 1 shows the resonator configuration used in this work, corresponding to the grazing incidence geometry, with a single bounce (total internal reflection at the pump facet) of the laser beam.

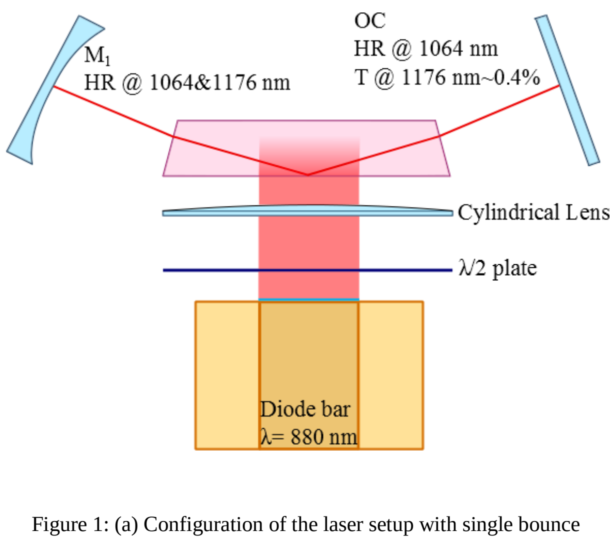

Figure 1: (a) Configuration of the laser setup with single bounce

The crystal was an a-cut Nd:YVO_4 crystal (Crystech) with 1.1 at. % Nd^{+3} doping concentration and dimensions of 22x5x2 mm^3, with the c-axis orientation perpendicular to the larger surfaces. The 5x2 mm facets were cut with an angle of 5° to minimize possible parasitic self-lasing effects and were antireflection coated for 1064 nm and 1176 nm. The 22x5 mm surface, which was the pump surface, was coated for high transmission at 808 nm and 880 nm. The crystal was mounted on a copper heat sink refrigerated by 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. The absorption coefficients of this crystal were measured at the pump wavelength of 880 nm and are approximately13.4 cm^{-1} for π-polarized light (electric field parallel to the crystal's c-axis). A 70 watts TE-polarized diode bar (Jenoptik) was used as pump source and mounted on a heat sink (copper plate) using indium foil. Its temperature was controlled by a Peltier element and tuned to emit at 880 nm. An achromatic half wave plate (Thorlabs) was used to rotate the polarization, and hence access the higher absorption coefficient of the crystal in the π direction. In order to focus the pump beam into the crystal a 6.4 mm focal cylindrical lens was used generating a sheet with line focus of approximately 50 μm in the vertical direction and 12 mm in the horizontal direction.

The whole cavity was approximately 7 cm long comprising two mirrors. Mirror M_1 was a high reflector (R> 99.99 %) at 1064 nm and at 1176 nm with 15 cm radius of curvature and M2 a flat output coupler with R>99.99 % at 1064 nm and T=0.47 % at 1176 nm. With this configuration the laser operated multimode and, depending on the alignment of the mirrors, a variety of pure Hermite-Gaussian laser modes could be obtained, including TEM_{00}.

The pump pulses of the quasi-continuous (qcw) regime, had duration of 150 μs and repetition rate of 20 Hz. The laser output consisted of the Raman emission at 1176 nm and a small leaking output at the fundamental wavelength of 1064 nm. In order to measure only the Raman laser, a longpass filter was used (FEL1150 Thorlabs) before the energy sensor (Thorlabs - ES111C). The laser spectrum was recorded with a NIR spectrometer (Ocean Optics NIR-Quest).

3. Results

The spectra of the Raman laser emission at 1176 nm is shown in Fig. 2(a). In multimode operation, a maximum output power of 8.2 W was obtained, corresponding to a slope efficiency of 15.3 %. Raman laser threshold was 16.7 W, as shown in Fig. 2(b).

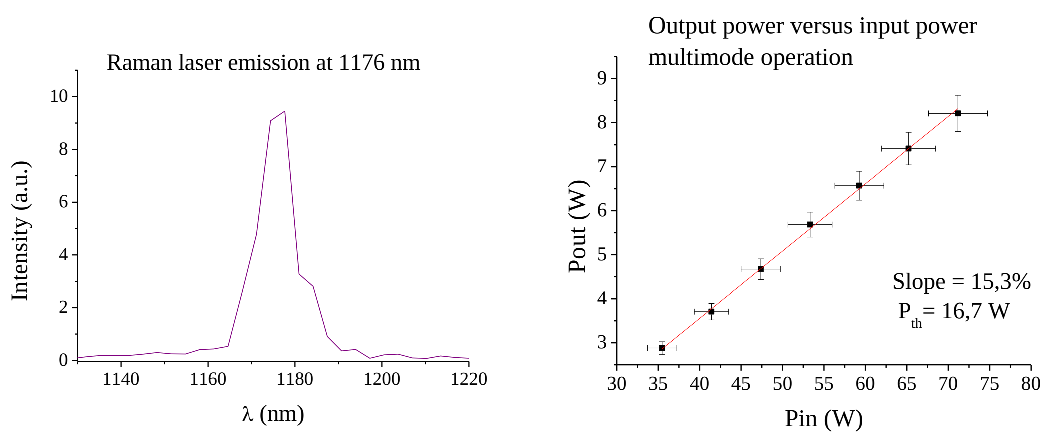

Figure 2: (a) Emission spectrum of the Raman laser, centered at 1176 nm; (b) Output power versus diode input power, with multimode operation of the Raman laser at 1176 nm.

The beam quality factor M² was measured for the TEM_{00} mode with a CCD using the second moment method and the value obtained was below M^2=1.5.

By re-aligning the mirrors in order to change the oscillating Raman laser mode inside the cavity, it was possible to obtain TEM_{00}, TEM_{10}, TEM_{20}, TEM_{30}, TEM_{40}, TEM_{01} and TEM_{11} modes, as shown in Fig. 4(a). A strong blue emission from the crystal was also observed when there was Raman laser action, which is attributed to fluorescence of Tm^{3+} impurity ions [7]. This effect makes it possible to visualize the path of the beam inside the crystal, as seen in Fig. 4(b).

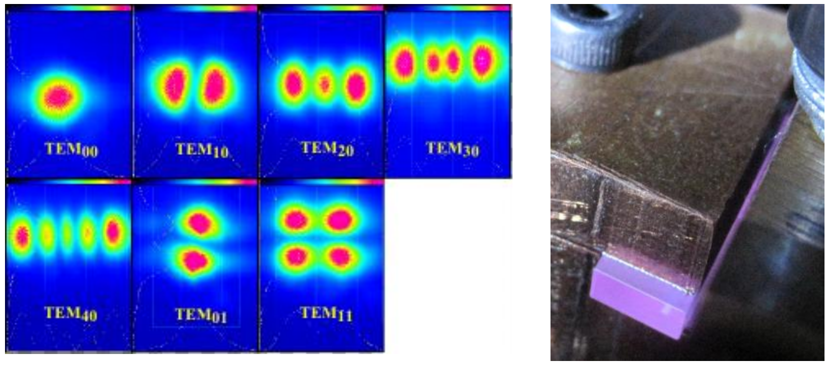

Fig. 4 (a): TEM modes obtained using the grazing incidence Raman laser configuration; (b) Blue fluorescence of the Nd:YVO_4 crystal, showing the laser beam path.

4. Discussion

In this work we reported, for the first time to our knowledge, a diode-side-pumped, qcw Nd:YVO_4 self-Raman laser emitting at 1176 nm. The Raman laser operates in a variety of Hermite-Gauss laser modes depending on mirror alignment, including TEM_{00}. Stable TEM_{00} mode operation was achieved with a beam quality parameters of less than 1.5. For multimode operation, a maximum output power of 8.2 W and a slope efficiency of 15.3% were obtained.

5. Acknowledgements

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6. References

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