High Efficiency 1341 nm Nd:GdVO₄ Laser in-Band Pumped at 912 nm¹

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Abstract—A high-efficiency 1341 nm Nd:GdVO₄ laser in-band pumped at 912 nm is demonstrated for the first time. Using an all-solid-state Nd:GdVO₄ laser operating at 912 nm as pump source, 542 mW output was obtained with 1.14 W absorbed pump power. The slope efficiency with respect to the absorbed pump power was 56.6%, and the fluctuation of the output power was better than 2.6% in the given 30 min. The beam quality factor M² is 1.15.

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1. INTRODUCTION

Nd-doped vanadate crystals are characterized by their high absorption and emission cross sections [1–32]. The four-level 1.3 µm continuous-wave laser emission was recently investigated for Nd:YVO₄ [33–36], Nd:YAG [37, 38], and Nd:GdVO₄ [39, 40] crystals. The corresponding frequency doubled red lasers were also in moderate progress [41–45]. Consequently, serious thermal lens [46, 47] effect arises basically result from the relatively high quantum defect between the lasing wavelength and the pump wavelength. Therefore, the performances are still limited and the full lasing potential is not yet exploited. A more efficient pumping method was presented recently, which was to pump the Nd³⁺ ions directly into the ⁴F₃/₂ upper lasing level. This method was used successfully in case of the Nd:YAG laser [48–54]. However, only several works about 1.3 µm emission by direct pumping were reported. In 2005, a 1.3 µm continuous-wave Nd:GdVO₄ laser pumped by a 879 nm Ti:Sapphire laser was reported, with a slope efficiency of 60.7% [55]. In 2009, a 1.3 µm continuous-wave Nd:YVO₄ and Nd:GdVO₄ laser pumped by a 879 nm diode laser was reported, with a slope efficiency of 43% [56]. Recently, the 1342 nm Nd:YVO₄ laser under direct 914 nm pumping was reported [57]. To the best of our knowledge, the 1341 nm Nd:YVO₄ laser under direct 912 nm pumping have not been reported. In this work, we achieved an output power of 542 mW at 1342 nm for an absorbed pump power of 1.14 W, corresponding to an optical-to-optical conversion efficiency of 47.5%. The fluctuation of the output power was better than 2.6% in the given 30 min.

² The article is published in the original.

2. EXPERIMENTAL SETUP

A simple plano-concave cavity was employed to generate the 1341 nm laser, as shown in Fig. 1. The pump source of the 912 nm Nd:GdVO₄ laser was an 808 nm fiber-coupled laser diode array with a fiber core diameter of 400 µm and a numerical aperture (NA) of 0.22. A multi-lens coupler reimaged the pump beam into a Nd:GdVO₄ crystal with a ratio of 1:1. The 3 × 3 × 5 mm³ crystal was 0.2-at % doped and a-cut. Its entrance face was coated for highly reflective (HR, R > 99.5%) at 912 nm and highly transmissive (HT, T > 95%) at 808 nm. The other face has antirefection (AR, R < 1%) coating at 912 nm. The crystal warped in indium foil was mounted in a cooper heat sink which cooled by refrigerant water at 15°C. A concave mirror with 150 mm radius of curvature and 5% transmittance at 914 nm was used as output coupler. The cavity length of 914 nm laser was 15 mm. It could provide 2.8 W maximum output power under 18.5 W incident LD pump power, with spectral line-width of 1.1 nm.

F was a focus lens with 40 mm focal length. It was used to control the 912 pump beam radius to realize better volume matching between pump and oscillating beam in the second Nd:GdVO₄ crystal utilized as 1341 nm laser gain medium a Nd:GdVO₄ crystal 1.0-at % doped, 3 × 3 × 8 mm³ was chosen in the experiment. The Nd:GdVO₄ crystals, both surfaces were antireflective (AR) coated at 1341 nm and highly transmissive (HT) coated at 914 nm, were wrapped in indium foil and clamped in a copper holder. M1 was a plane mirror highly reflective coated at the lasing wavelength of 1341 nm. Plane output coupler M2 was coated for 5% transmittance at 1341 nm. It was also coated HT at 1063 nm to prevent that from resonating and HT at 914 nm to make the measurements of absorption more accurate.
3. RESULTS AND DISCUSSION

The output power versus the absorbed pump power is shown in Fig. 2. When the absorbed pump power is 1.14 W, the laser yielded 542 mW of cw output power at 1341 nm. The absorption efficiency of the second Nd:GdVO₄ crystal versus was 55.2%. The absorbed pump power at threshold of laser oscillation was 16 mW and the slope efficiency with respect to the absorbed pump power was 56.6%.

The beam quality of the 1341 nm emission measured by a Laser Beam Diagnostics is shown in Fig. 2 inset, the beam quality M² factor value was equal to 1.15 at the maximum output power. Figure 3 shows the spectra of output power of 542 mW which was detected using the high resolution spectrometer.

4. CONCLUSIONS

In summary, we have demonstrated a diode-pumped Nd:GdVO₄ laser emitting at 1341 nm with a maximum cw output power of 542 mW for 1.14 W of absorbed pump power at 912 nm. Further improvements of these results are in progress by optimizing the output mirror transmission and using a new laser resonator. Moreover, a proper choice of the laser crystal doping level and length would enable efficient absorption of the pump radiation at 912 nm. Thereby, 1342 nm emitting lasers pumped by a laser diode at 912 nm with improved performances will be obtained. Furthermore, this will allow realization of efficient laser sources that generates red light at 670.5 nm by intracavity frequency doubling of the 1341 nm fundamental wavelength.

REFERENCES