Characterization of 0.5 At % Nd Doped YVO_4 Pumped by Diode Laser

Noriah Bidin* and Ganesan Krishnan

Laser Research Group, Research Alliance Nanotech, Department of Physics,
Faculty of Science, Universiti Teknologi Malaysia
**Email: noriah@utm.my, Tel: 607-5534187, Fax 607-5566162*

Abstract. The output of diode laser pumped 0.5 at % Nd doped vanadate YVO_4 crystal bar was characterized. Diode laser has wavelength centered at 808 nm. The pump power was focused to localize the high power density of source at the crystal bar surface. The output of diode pumped vanadate crystal was detected by a spectrum analyzer. The output radiation is centered at 1064 nm with linewidth of 1.15 nm. The stimulated emission cross section was estimated to be 14.94×10^{-19} cm^2. The intensity of the fluorescent beam was measured by powermeter and permanently recorded by using CCD video camera. The beam spot is TEMoo mode with beam divergence of 0.4° with the absent of intracavity. The optical –to-optical slope efficiency is found to be as 4.8 % with threshold power of 1404 mW.

Keywords: Nd:YVO_4 crystal, pump power, threshold, conversion efficiency, doping level, laser diode
PACS: 42.55.Px , 42.55.Xi and 42.70.Mp

INTRODUCTION

The first optical research on Nd:YVO_4 laser crystal was founded by O'Connor in 1966 [1]. However, Nd:YVO_4 crystal only aggressively studied after 1990 due to the difficulties in growing the high optical quality crystal in large dimension [2]. Furthermore, the development of laser diode also accelerated the progress of Nd:YVO_4 laser crystal researches due to its amenability as laser diode pumping [3]. Nowadays, laser diode pumped solid state devices is very common due to its high efficiency, compactness, high stability, long lifetime and good beam quality [3]. Nd:YVO_4 has very attractive features, such as high absorption of pump wavelength at 809 nm and a large stimulated emission cross section [4-8].

In general the performance of Nd:YVO_4 laser crystal is dependent on the neodymium doping concentration and length of the crystal [3, 4, 5]. Typically, 1 at % Nd-doped YVO_4 crystal is commonly used as a gain medium having the length in a few millimeter long [6]. On the other hand, it is claimed that decreasing the neodymium doping concentration and lengthening the crystal can reduce thermal effect during laser pumping [7]. However, it is preferred to keep the length of the crystal short due to ever shrinking device size while reduces neodymium doping concentration to withstand high pump power.

Therefore, in this present paper, the characteristic of 0.5 at % Nd-doped YVO_4 laser crystal with 1 mm length was studied. The performance is measured base on the optical conversion efficiency.

EXPERIMENTAL

Figure 1 shows the simplified schematic diagram of the experimental set up. An Applo diode laser manufactured from USA was employed a pumping source. Its wavelength centered at 808 nm with bandwidth of 3 - 4 nm. This diode laser has variable output with a maximum power of 8 W. The laser operated at continuous wave cw with Gaussian mode of TEM_{oo}. In this particular experiment the pumping current was conducted in the range of 7 – 14 A.

Enabling Science and Nanotechnology
AIP Conf. Proc. 1341, 272-274 (2011); doi: 10.1063/1.3587000

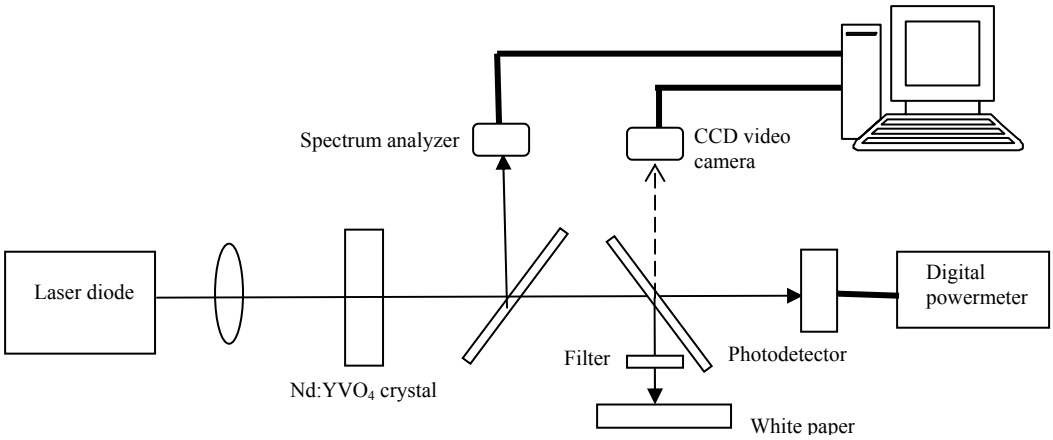

FIGURE 1: Schematic diagram of experimental set-up.

The dimension of the vanadate Nd:YVO_4 crystal was 5 mm × 5 mm × 1 mm. The concentration was 0.5 at % Nd doped vanadate YVO4 crystal. Its refractive index is 1.96 and have fluorescent lifetime of 90 μs. This crystal was coated with high transmission coating at 808 nm and high reflection coating at 1064 nm on its front face while high transmission coating at 1064 nm on the back face. The crystal was a-cut due to anisotropic characteristics of Nd:YVO_4 laser crystal.

In order to ensure proper heat transfers between the crystal to the copper holder, the crystal was wrapped with pure indium foil. The assembly of the crystal and cooper holder was placed on a thermoelectric cooler TEC for thermal management.

The laser diode was focused on the laser crystal via a biconvex lens with 25 mm focal length. In the absence of filter to block the pump beam, the crystal was slightly tilted to separate the pump beam from the output beam of Nd:YVO4. The spectrum of fluorescence beam was detected via a Wavestar spectrometer. The power of the fluorescence beam of the vanadate crystal was measured using a broadband Melle Griot powermeter. In practice, an infrared IR card was conducted to detect the existence of IR beam. However for recording purpose, a white screen was utilized and a Toolpix CCD video camera was used to permanently recording the beam spot.

RESULTS AND DISCUSSION

The spectrum of fluorescence beam from Nd:YVO_4 crystal is shown in Figure 2. The wavelength of the beam is centered at 1063.98 nm with a narrow linewidth Δλ of 1.15 nm. The emission cross section at wavelength of 1064 nm, has a peak value of about 14.94×10^{-19} cm^2 which almost 5 time greater than Nd:YAG crystal. This result is in good agreement with other researcher [4] by taking into account the experimental errors.

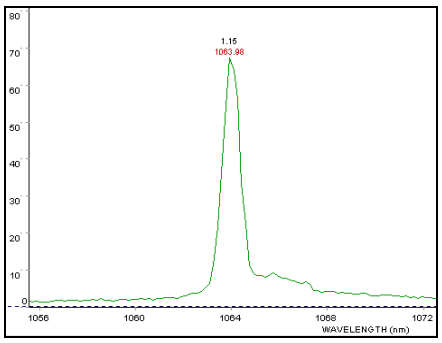

FIGURE 2: Spectrum of fluorescence beam of Nd:YVO_4

FIGURE 3: The beam spot of the Nd:YVO_4 fluorescence beam. Mag. 1X

Most of the incident light from intense pump absorption of 808 nm laser diode radiation was absorbed on the 1 mm thickness of the vanadate crystal. The spot size of the output beam can best match with the absorption pump radiation in a short length. The recorded beam spot is shown in Figure 3.

A single beam spot appeared indicated that the beam has Gausian profile with TEM_{00} mode. It is better to note that due to the infrared nature, in real field the spot is invisible. However, the bluish output beam is realized after display on the monitor. The CCD camera sensor has converted the invisible into visible (bluish) beam spot. This particular image in Figure 3 was grabbed at a distance 80 cm from the crystal. The beam spot is expanded up to 12 mm in diameter. Hence the beam divergence is estimated to be almost 0.4 °. This is obtained without the collimation elements and the absent of intracavity.

The result of output power of 0.5 at % Nd-doped YVO_4 crystal at various input power is shown in Figure 4. An optical-to-optical slope efficiency of the crystal is 4.8 % with diode laser pumping at 808 nm. The threshold power of the crystal is found to be as 1404 mW. Such high power to start lasing is possibly due to the low thermal conductivity which prevents good heat dissipation and induced stress and thermal lensing.

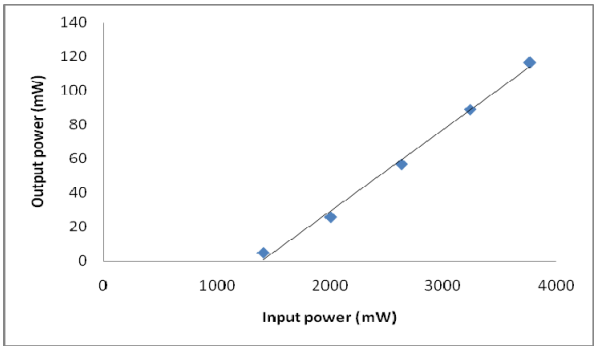

FIGURE 4. Output powers of 0.5 at % Nd-doped Nd:YVO_4 laser crystals at 1064 nm output

CONCLUSION

The performance of a vanadate crystal doped with 0.5 % at Nd has been investigated. The vanadate crystal was end pumped by diode laser at 808 nm. The output crystal is realized to have wavelength centered at 1064 with linewidth of 1.15 nm. The stimulated emission cross section of the beam is 14.94×10^{-19} cm^2. The transverse mode of the output from the vanadate crystal has TEMoo with beam divergence of 0.4°. The optical-to-optical slope efficiency is 4.8% with threshold power of 1404 mW.

ACKNOWLEDGEMENT

We like to express our thanks to Nanotech Research Alliance for the financial support for attending this nanotech conference. Thanks are also due to the Malaysia government through Sciencefund grant vote 73989 to partially support in this project. We also thanks to the Research Management Center for their cooperation in the management of the project.

REFERENCES

1. F. S Ermeneux., C.Goutaudier, R. Moncorge, M. T., Cohen-Adad Bettinelli M. and E. J. Cavalli of Optical Materials **13**, 193-204, 1999.
2. X.Meng, L.Zhu, H. Zhang, C.Wang, Y.T Chow., M.Lu J. of Crystal Growth. **200**, 199-203, 1999.
3. R Paschotta. Encyclopedia of laser physics and technology. Berlin: Wiley-VCH 2008.
4. W Koechner. Solid state Laser Engineering. New York :Springer-Verlag. 2006.
5. H Zhang., J Liu., J.Wang, C.Wang, L.Zhu, Z.Shao, X.Meng, X.Hu, Y.T. Chow and M. Jiang. J. of Optics and Lasers in Engineering **38**, 527-536, 2002.
6. Z. Wang, L.Sun, S.Zhang, X.Meng, R. Cheng, Z. Shao. J. of Optics and Laser Technology **33**, pp. 47-51, 2001.
7. X.Ding, R.Wang, H.Zhang, X.Y. Yu., W.Q.Wen, P.Wang, J.Q Yao. J of Optics Communications **282**, 981-984, 2009.
8. W. T. Silfvast Laser Fundamentals 2nd ed. Cambridge: Cambridge University Press. 2004.
9. H.Zhang, M.Chao, M.Gao, L.Zhang and J.Yao J. of Optics & Laser Technology **35**, 445 – 449, 2003.