Experimental spectra study of $Tm:GdVO_4$ microchip laser at room temperature

Yufeng Li (李玉峰)[1], Youlun Ju (鞠有伦)[1], Y. Urata[2], and Yuezhu Wang (王月珠)[1]

[1]*National Key Laboratory of Tunable Laser Technology, Harbin Institute of Technology, Harbin 150001*

[2]*Megaopto Co. Ltd., 11-58-307 Honcho, Wako, Saitama 351-0114, Japan*

Received December 8, 2006

A high efficient diode-pumped $Tm:GdVO_4$ microchip laser is demonstrated. Output power of 310 mW at 1917 nm with slope efficiency of 22% is produced when pumped by 2 W of power at 802 nm. Unpolarized fluorescence spectra near 1800 nm pumped by laser diode are measured. In addition, the most important upconversion fluorescence from $^1D_2$ to $^3F_4$ and $^3H_6$ levels is discussed.

OCIS codes: 140.3580, 140.3480, 140.3070.

Tm ion is an attractive activator because AlGaAs laser diode (800 nm) is suitable for pumping the energy transition of Tm from $^3H_4$ to $^3H_6$; the tunable 1.9-μm ($^3F_4 - {}^3H_6$) emission lies in the eye-safe region and includes strong absorption lines of water. Thus, a miniature Tm-doped solid-state laser is expected to apply to medicine and remote sense. $GdVO_4$, a promising laser crystal[1], shows the advantages in $Nd:GdVO_4$ lasers compared with Nd:YAG and $Nd:YVO_4$[2]. Oscillation of $Tm:GdVO_4$ was reported by Wyss *et al.* in 1998[3,4]. In 2005, Urata *et al.* reported an 808-nm diode-pumped continuous wave (CW) microchip $Tm:GdVO_4$ laser with 420-mW output power at 1915 nm[5]. Tm-doped $GdVO_4$ laser at low temperature is got in our experiment with output power of 2 W. In this paper, the absorption and emission spectra of $Tm:GdVO_4$ are measured, a CW diode-pumped $Tm:GdVO_4$ laser is built, and upconversion spectrum is discussed.

The crystal with 3% Tm^{3+} concentration[6] was grown by the Czochralski crystallization method[7]. The sample is a-cut with dimension of 3×3 (mm) in cross section and 2 mm in length. Figure 1 shows the polarized absorption coefficient of $Tm:GdVO_4$ near 800 nm at room temperature. The faces are polished plane, parallel, and coated antireflection coated near both 800 and 1900 nm with reflectivity $< 0.5\%$.

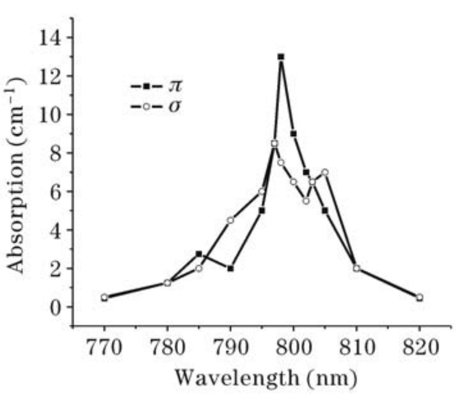

Fig. 1. Polarization-resolved absorption spectra of $Tm:GdVO_4$ with concentration of 3% Tm at room temperature.

Figure 2 illustrates the unpolarized fluorescence spectrum measured at room temperature for the energy level transition $^3F_4 - {}^3H_6$ by using InGaAs photo detector. Irrespective of the polarization of the incident beam, the $Tm:GdVO_4$ sample emitted the fluorescence around 1.7—2.0 μm with more than 100-nm width. The maximum fluorescence intensity at 1836 nm was found.

The cavity configuration[8] of the diode-pumped $Tm:GdVO_4$ laser is illustrated in Fig. 3. The fiber-coupled diode laser (802 nm) is shaped by lens L1 ($f = 50$ mm) and then focused into the $Tm:GdVO_4$ crystal by lens L2 ($f = 35$ mm). The focus point in the crystal is 140 μm in diameter. The mirror is coated high-reflection near 1.9 μm ($R > 99.5\%$), the output coupler is plane-concave with the radius of curvature of 50 mm and 2% transmissivity near 1.9 μm. The typical length of cavity is 25 mm.

The performance of free running $Tm:GdVO_4$ microchip

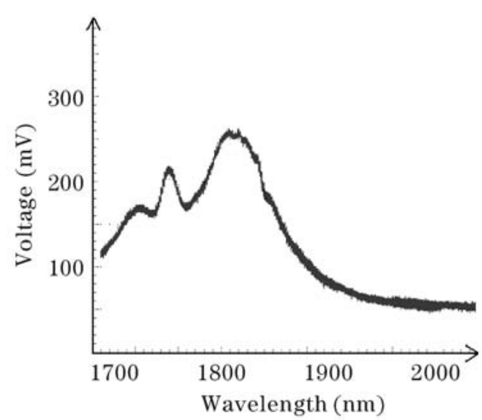

Fig. 2. Unpolarized fluorescence spectrum for $Tm:GdVO_4$ ($^3F_4 - {}^3H_6$).

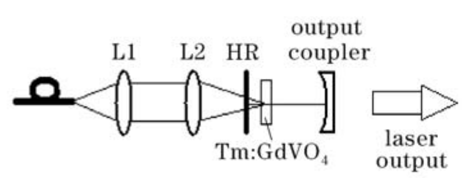

Fig. 3. Cavity configuration of the diode-pumped $Tm:GdVO_4$ laser.

1671-7694/2007/060351-02

laser is displayed in Fig. 4. The output power of 310 mW (slope efficiency $\eta = 21.8\%$) with 2% output coupler transmission is obtained for 2 W of absorb power. The output laser wavelength is 1917 nm with linewidth of 12 nm (full-width at half-maximum (FWHM)).

Figure 5 gives a illustration of the important transitions between Tm^{3+} energy levels involved in our experiment. Under 2-W pump power, the initial 802-nm photon is absorbed into the $^3H_4$ state, followed by nonradiative relaxation to the $^3H_5$ state, then another 802-nm photon is absorbed to the $^1G_4$ state, followed by relaxation to the $^3F_{2,3}$, the third 802-nm photon is absorbed to the $^1D_2$ state. 440- and 361-nm photons are produced from the transition $^1D_2 - {}^3F_4$ and $^1D_2 - {}^3H_6$ states. Figure 6 shows the spectrum of upconversion detected by photon-multiplier phototube. The peaks of 361 and 440 nm are caused by the split of energy level. Transition from $^1G_4$ to $^3H_6$ is not observed in this experiment. It can be concluded that under high power CW pumped laser, $^1D_2$ is the main level to get upconversion fluorescence. This transition is a way to get CW blue or ultraviolet upconversion laser from Tm-doped crystal pumped by high power diode laser.

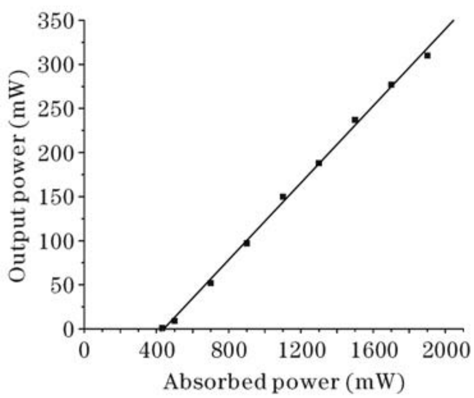

Fig. 4. Performance of microchip Tm:$GdVO_4$ laser with output coupler of 2%.

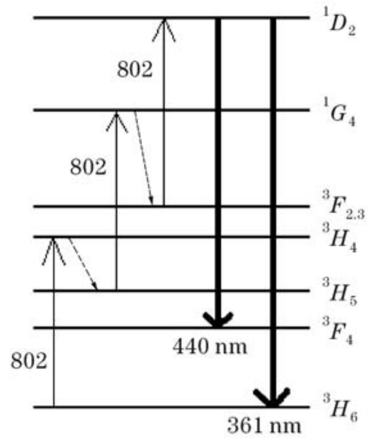

Fig. 5. Schematic diagram of upconversion of Tm^{3+} energy levels.

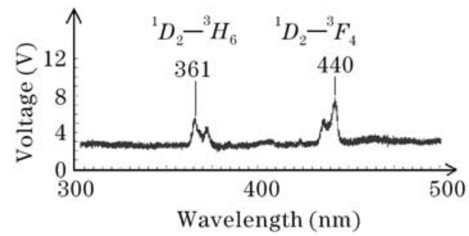

Fig. 6. Spectrum of upconversion of Tm^{3+} in $GdVO_4$.

In conclusion, high efficient CW microchip Tm:$GdVO_4$ laser in the 1.9-μm region is demonstrated. Output power of 310 mW with slope efficiency of 22% is produced by this laser when it is pumped by 2 W of power at 802 nm. Polarization-resolved absorption spectra near 800 nm and unpolarized fluorescence spectra near 1800 nm pumped by laser diode are measured. In addition, the most important upconversion fluorescence from $^1D_2$ to $^3F_4$ and $^3H_6$ levels is detected.

Y. Li's e-mail address is lyf18@163.com.

References

1. Y. Urata, K. Akagawa, S. Wada, H. Tashiro, S. J. Suh, D. H. Yoon, and T. Fukuda, Cryst. Res. Technol. **34,** 41 (1999).
2. C. Q. Wang, Y. T. Chow, L. Reekie, W. A. Gambling, H. J. Zhang, L. Zhu, and X. L. Meng, Appl. Phys. B **70,** 769 (2000).
3. C. P. Wyss, W. Luthy, H. P. Weber, V. I. Vlasov, Y. D. Zavartsev, P. A.Studenikin, A. I. Zagumennyi, and I.A.Shcherbakov, Opt. Commun. **153,** 63 (1998).
4. C. P. Wyss, W. Luthy, H. P. Weber, V. I. Vlasov, Y. D. Zavartsev, P. A. Studenikin, A. I. Zagumennyi, and I. A. Shcherbakov, IEEE J. Quantum Electron. **34,** 2380 (1998).
5. Y. Urata and S. Wada, Appl. Opt. **44,** 3087 (2005).
6. Y. Li, B. Yao, and Y. Wang, Chin. Opt. Lett. **4,** 175 (2006).
7. S. Lin, W. Xiong, L. Li, and Y. Xie, J. Cryst. Growth **270,** 133 (2004).
8. B. Yao, L. Dong, Y. Wang, Y. Ju, X. Yu, W. Sun, and Y. Li, Acta Opt. Sin. (in Chinese) **24,** 79 (2004).