Diode-pumped CW Tm:$GdVO_4$ laser at 1.9 μm

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A high power cryogenic cooling Tm-doped (2%) $GdVO_4$ laser double-end-pumped by fiber-coupled-diode with the center wavelength of 804.5 nm at 21 °C is reported. The highest continuous-wave (CW) power of 2.35 W at 1903 nm is attained at pump power of 24 W. The slope efficiency is 12.5% and the threshold is 3.2 W. Single- and double-end-pumped types are investigated.

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In recent years, laser action in trivalent thulium (Tm^{3+}) has seen rapid development. The main interest in the 2-μm laser on the $^3F_4 \rightarrow {}^3H_6$ transition arises from its application in medicine and remote sensing[1−4]. $GdVO_4$, as the host crystal for Tm, offers many favorable properties, the absorption cross section of Tm in $GdVO_4$ is considerably stronger and broader (770—820 nm) than that in YAG[5,6], and the spectrum is shifted closer to the emission wavelength of commercially available AlGaAs laser diodes.

Figure 1 shows the absorption spectra for 2%-Tm-doped $GdVO_4$ by using π and σ polarized incident lights.

The broad emission spectrum (1.9—2.1 μm) allows for tuning the laser wavelength and generating short pulses. Furthermore, the large thermal conductivity of $GdVO_4$ (11.7 W/(m·K) at 300 K) is very favorable for efficient cooling of the crystal. In spite of all these promising properties of $GdVO_4$, there are only a few reports on laser action in Tm:$GdVO_4$ crystal on the $^3F_4 \rightarrow {}^3H_6$ transition. Urata *et al.* have studied continuous-wave (CW) Tm:$GdVO_4$ laser with output power of 700 mW at 1915 nm and the slope efficiency is 25%[7]. Wyss *et al.* have got output power of 1.4 W at 1.9 μm from the diode-pumped Tm:$GdVO_4$ laser[8]. In this paper, we report a diode-pumped Tm:$GdVO_4$ laser at 1.9 μm with the maximum output power of 2.35 W.

The experimental setup is shown in Fig. 2. The fiber-coupled diode laser (808 nm) is shaped by lens L1 (f = 35 mm) and then splited by R1 ($T = R = 50\%$ at 808 nm) to realize double-end-pumped cavity. R2, as same as R3 and R4, is high-reflection plane mirror at 808 nm. Two beams are focused into the Tm:$GdVO_4$ crystal by L2 (f = 50 mm) and L3 (f = 75 mm). The Tm:$GdVO_4$ crystal is 4 × 4 (mm) in cross section and 10 mm in length, the concentration of Tm is 2%. HR1 and HR2 are high-reflection plane mirrors near 1.9 μm ($R > 98.5\%$), the output coupler is plano-concave lens ($f = -300$ mm) with transmissivity $T = 2\%$. In order to reduce thermal effect and up-conversion, the crystal is put on heat-sink cooled by liquid nitrogen and the laser operates at the temperature of 77 K, this is because that the traditional grown crystal has many scattering centers which increase the loss in laser cavity, when the crystal operates at room temperature, the threshold is high enough to destroy the crystal. The typical length of L-type cavity is about 150 mm.

To find the optimum wavelength of pump laser, we let the diode laser operate at different temperatures (the

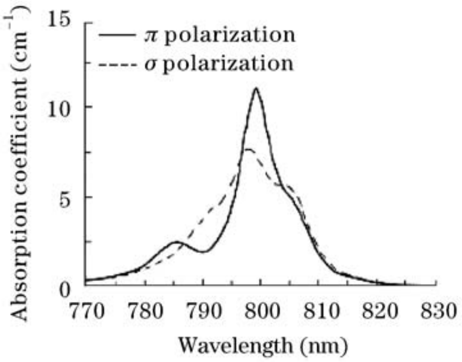

Fig. 1. Polarization-resolved absorption spectra of 2%-Tm-doped $GdVO_4$.

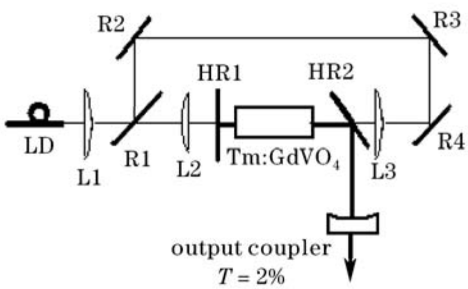

Fig. 2. Experimental setup of diode-pumped Tm:$GdVO_4$ laser.

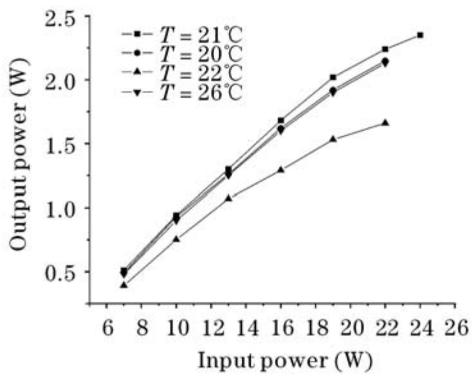

Fig. 3. Output power versus input power when diode laser operates at 20, 21, 22, and 26 °C.

wavelength can be changed by running temperature of diode in a small range) and find the relationship between input power and output power. As shown in Fig. 3, the optimum running temperature is 21 °C with the center wavelength of about 804.5 nm, maximum output power is 2.35 W and slope efficiency is 12.5%. There is no obvious difference between the lines at 22 and 20 °C. When the diode laser operates at 26 °C, the output power and slope efficiency (8%) are much lower than others.

We investigated single- and double-end-pumped system, as shown in Fig. 4. The threshold of double-end-pump is 3.2 W which is much lower than that of 13 W in single-end-pumped system, this is because that the re-absorption and thermal effect in local area in single-end-pumped crystal are very heavy. It is necessary to use double-end-pumped system to increase the length of active region, reduce re-absorption effect, lower local heat congestion and then decrease threshold. The slope efficiencies of two types are approximate 12.5%

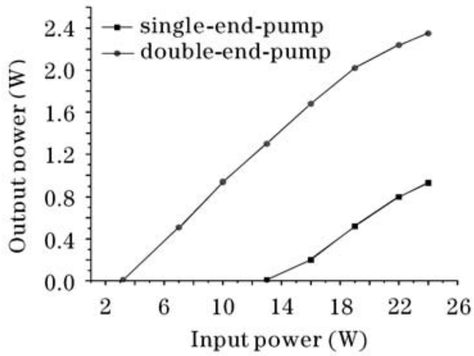

Fig. 4. Output power versus input power of single- and double-end-pumped systems.

for double-end-pump and 11% for single-end-pump. The maximum output power is 2.35 W at 1903 nm with linewidth of 2.6 nm (FWHM). The output transversal mode is TEM_{00}.

In this experiment a diode-pumped 2.35-W CW $Tm:GdVO_4$ laser is demonstrated, the threshold is 3.2 W and slop efficiency is 12.5%. The optimum pump wavelength is 804.5 nm when the diode laser operates on 21 °C. For higher power and conversion efficiency in the future, it is needed to optimize Tm concentration, crystal length, and resonator parameters, this work is still in progress.

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