High efficient diode-pumped Tm:YAP laser at room temperature

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Received December 8, 2006

A high efficient diode-pumped Tm:YAP laser is reported. The maximum output power at 1981 nm is 5.2 W and the slope efficiency is 30%. Unpolarized absorption near 800 nm and unpolarized fluorescence spectra near 1800 nm pumped by laser diode (LD) are measured. In addition, the relationship between operation temperature and output power is discussed.

OCIS codes: 140.3580, 140.3480, 140.3070.

Diode-pumped lasers based on thulium-doped hosts is a subject of considerable interest in recent years since their emission wavelength lies in the attractive 1.8—2 μm region[1] and they can be directly diode-pumped with high efficiency. This paper focuses on the lasing characteristics of thulium-doped $YAlO_3$ (Tm:YAP)[2,3] crystals. Similar to the YAG host, the YAP crystal has the advantages of high mechanical strength and large heat conductivity (0.11 W/(cm·K) in YAP versus 0.13 W/(cm·K) in YAG)[4], which allows high-power operation with reduced risk of fracture. In addition, Tm:YAP has broad tunability around 2 μm and polarized laser emission due to the biaxial nature of the YAP host. In 1997, a 3-W laser diode (LD) in an end-pumped geometry was used to generate 730 mW of Tm:YAP laser output, which represents a conversion efficiency of 42% in terms of absorbed pump power[5]. In 2006, the maximal output of 4.8 W was obtained from diode-pumped Tm:YAP laser[6]. The free running wavelength was measured at 1.99 μm with optical-to-optical efficiency of 48%.

In this work, we demonstrate the continuous-wave (CW) lasing in the 3%-Tm-doped YAP crystal. Spectroscopic measurement of the active material and CW laser performance are reported and discussed. The diode-pumped oscillator shows a maximum output power of 5.2 W at 20-W pump power, a slope efficiency of 30%, and the free running wavelength of 1981 nm.

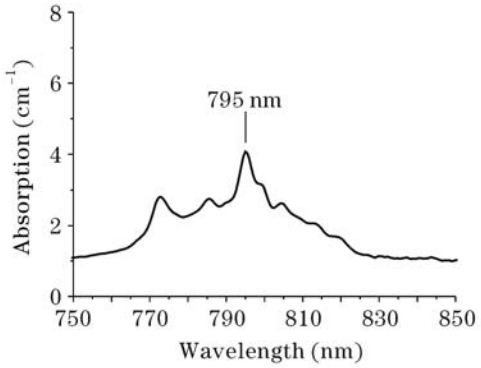

Fig. 1. Absorption spectrum of Tm:YAP at room temperature.

The 3%-Tm^{3+}-doped sample is a-cut with dimension of 4×4 (mm) in cross section and 8 mm in length. The faces are polished plane, parallel, and coated antireflection near both 795 and 1980 nm with reflectivity $< 0.5\%$. Figure 1 shows the unpolarized absorption coefficient of Tm:YAP near 795 nm 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 photodetector. The maximum fluorescence intensity was found at 1858 nm. Usually, in the laser cavity, because of the reabsorption, the output wavelength is not at peak of fluorescence wavelength but another peak in the wings of the fluorescence spectrum curve. In this experiment, the wavelength of free running Tm:YAP laser is 1981 nm.

The cavity configuration[7,8] of the diode-pumped Tm:YAP laser is illustrated in Fig. 3. The fiber-coupled diode laser (795 nm) is shaped by L1 ($f = 25$ mm) and then focus into the Tm:YAP crystal (4×4 (mm) in cross

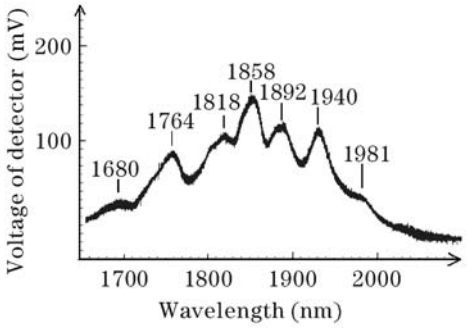

Fig. 2. Unpolarized fluorescence spectrum of 3% Tm:YAP.

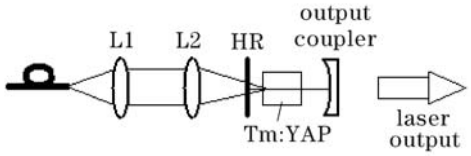

Fig. 3. Cavity configuration of the diode-pumped Tm:YAP laser. HR: high reflective plane mirror.

section and 8 mm in length) by L2 ($f = 50$ mm). The focus point in the crystal is 400 μm in diameter. The plane mirror HR is high reflective at the wavelength near 1.98 μm ($R > 99.5\%$). Different output couplers are used in this experiment. The typical length of the cavity is 30 mm and the operation temperature of the crystal is 18 °C.

Figure 4 gives the result of Tm:YAP laser under conditions of different pump powers and couplers. The maximum output powers of 5.2 W ($T = 5\%$) and 4.8 W ($T = 10\%$) are obtained under pump power of 20 W at 795 nm. The slope efficiencies are 30% and 27% respectively. The wavelength of free running laser is 1981 nm and the linewidth is 4 nm (full-width at half-maximum (FWHM)). When the scale of temperature controller is adjusted, the output power changes correspondingly. As Fig. 5 shows, the slope efficiency is 11.7 mW/K. This reveals that near room temperature, increasing the temperature of laser crystal is unfavorable to emit the heat that comes from pump power. For quasi-three-level laser system, the high temperature decreases the number of reversal particles, increases the threshold, and reduces the output power. In the range of room temperature, this output power change can be fitted linearly.

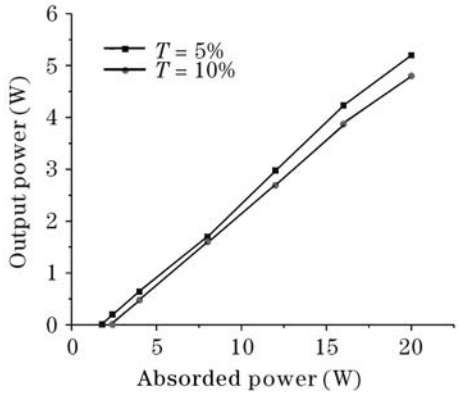

Fig. 4. Output power of Tm:YAP versus input LD power with two different couplers.

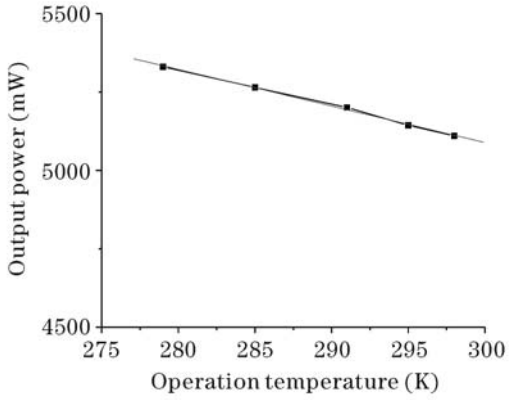

Fig. 5. Output power versus operation temperature.

In conclusion, a high efficient diode-pumped Tm:YAP laser is demonstrated. The maximum ourput power at 1981 nm is 5.2 W and the slope efficiency is 30%. At room temperature, the higher temperature that laser crystal operates on, the lower laser power it produces, the relationship can be fitted linearly.

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