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A linewidth-narrowed Tm:YLF laser using by two etalons

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ABSTRACT

A high power linewidth-narrowed Tm:YLF laser with two etalons was reported. 61.0 W of output power under incident pump power of 141.5 W was achieved, corresponding to an optical-to-optical conversion efficiency of 43.1% and a slope efficiency of 50.4%. The laser wavelength shift of only 0.12 nm with the incident pump power from 24.5 W to 141.5 W was observed.

1. Introduction

Solid-state lasers operating around 2 μm are useful for a variety of applications such as remote-sensing and medical [1–3]. Thulium-doped materials have several attractive features for generating light in this wavelength band, including a broad emission bandwidth, upper laser level has a long lifetime, absorption bands matched to high-power 800 nm commercially available diode laser, and the potential for high quantum efficiency due to a tow-for-one cross-relaxation process [4]. Therefore, high power Tm lasers have been widely investigated [5–8].

Yttrium lithium fluoride (YLF) is a naturally birefringent material, capable of producing linearly polarized output with virtually no depolarization loss. Furthermore, the refraction index of YLF decreases with temperature, leading to a negative thermal lens that is partly compensated by a positive lens effect due to end face bulging. Tm:YLF crystal has excellent spectroscopic properties which allow relatively low brightness diode pump sources to be used and has an emission spectrum that overlaps the main absorption lines of interest in Ho:YAG crystal. Unfortunately, the emission wavelength of Tm:YLF laser overlay the water vapor absorption peaks near 1.9 μm, which was easy to damage the AR coatings of the laser crystal. In order to obtain the high output power in Tm:YLF laser one must avoid the influence of water molecule absorption. For this reason, it is commonly used that enclosed the Tm laser in a dry box flushed with dry air. However, this adds extra complexity to the overall system. Another method is volume Bragg grating (VBG) as an element used in Tm:YLF lasers [9], has the capability of stabilization of laser wavelength. But this adds cost to the overall system.

In this work, two Fabry–Perot etalons were inserted in the cavity to force a Tm:YLF laser around at 1907.8 nm, 61.0 W of output power under incident pump power of 141.5 W was obtained with two Tm:YLF crystals without undoped end-caps. The corresponding slope efficiency was 50.4% and optical-to-optical conversion efficiency was 43.1%. The laser wavelength shift of only 0.12 nm with the incident pump power from 24.5 W to 141.5 W was observed.

2. Experimental setup

In the experiment, we used a dual rod resonator in a folded geometry in order to accommodate four laser diodes as pump sources. Two laser crystals were used to facilitate the use of four laser diodes as pump and to distribute the thermal load. Each laser crystal was end-pumped by two fiber-coupled laser diodes (*n*LIGHT Corp.) with a core-diameter of 400 μm and numerical aperture of 0.22. The emission center wavelength of each diode was about 792 nm at maximum output power of 50 W with temperature of 25 °C, and it can be tuned by changing the temperature of the heat sink to match the best absorption of the Tm:YLF crystal. The pumping light was refocused into the crystal with an approximately beam diameter of 1.1 mm by using coupling lenses with 15 mm and 41 mm focuses. Considering the transmission losses, nearly 95% of the pump power was incident on the laser crystal. Tm:YLF crystals with doped concentration of 3 at.% for the experiment were *a*-cut and had a cross section of 3 mm × 3 mm (*c*-axis, *a*-axis) and length of 16 mm (*a*-axis). Both end faces of the Tm:YLF crystals were antireflection coated for the laser wavelengths around 1.9 μm and the pump wavelength. To cool the Tm:YLF crystals they were wrapped

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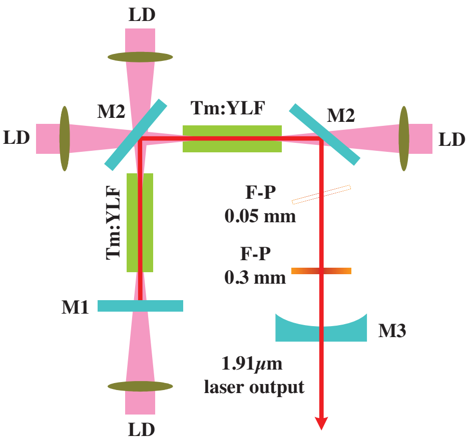
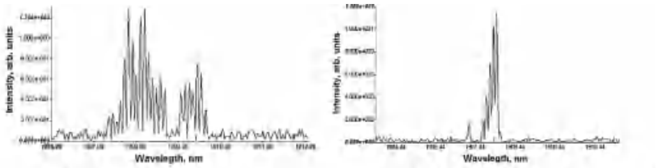
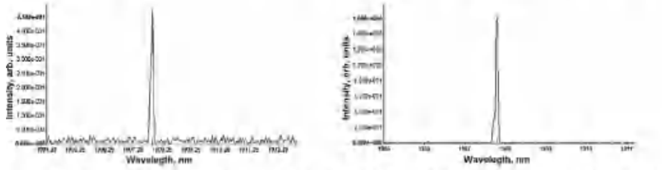


Fig. 1. Schematic of the experimental setup.



(a) free running at low power level (b) with 0.05mm F-P at low power level



(c) with two F-Ps at low power level (d) with two F-Ps at maximum output level

Fig. 2. Output spectrum of Tm:YLF laser.

in indium foil and clamped in a copper crystal-holder held at a temperature of 18 °C with a thermoelectric cooler.

Fig. 1 shows the schematic of the folded resonator geometry. The flat high reflector (M1) ($R > 99.7\%$ around the 1.9 μm) acts as a resonator mirror and also high transmits the pump radiation ($T > 98\%$ at 792 nm). The flat 45° dichroic mirror (M2) was high reflectivity ($R > 99.7\%$) around the 1.9 μm and high transmission at the pump wavelength ($T \sim 95\%$). The output coupler was a plano-concave mirror (M3) with a 200 mm radius of curvature, and it was coated with 30% transmittance at 1.91 μm. The physical resonator length was approximately 140 mm. Two F–P etalons (0.3 mm in thickness YAG and 0.05 mm in thickness YAG) with no coating were inserted in the cavity to restrict the wavelength of the Tm:YLF laser.

3. Experimental results

In the experiment, laser wavelength was measured by the EXFO WA-650 spectrum analyzer combined to a EXFO WA-1500 wavemeter. The output spectrum of Tm:YLF laser is shown in Fig. 2. We observed the free running spectrum of Tm:YLF laser at low output level, as shown in Fig. 2(a). The linewidth was wider, it laid over the water vapor absorption peak near 1907 nm and 1909 nm, this absorption leads to the output power fluctuations, and it will cause the Tm:YLF crystal defence of the AR coatings damage. When 0.05 mm YAG F-P was inserted in the cavity, the central wavelength of 1907.8 nm with linewidth of 0.4 nm was achieved, as shown in Fig. 2(b). When 0.3 mm YAG F-P was inserted in the cavity, the central wavelength of 1907.78 nm with linewidth of 0.15 nm was achieved, as shown in Fig. 2(c). Finally, the output central wavelength of Tm:YLF laser with two F–Ps was measured to be 1907.9 nm under incident pump power of 141.5 W.

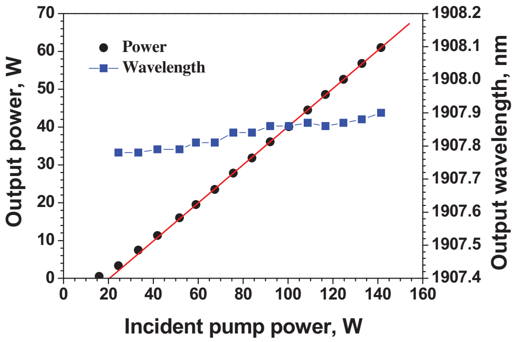


Fig. 3. The output power and wavelength of Tm:YLF laser with two etalons.

The power meter used in the experiment was Coherent PM150. Fig. 3 depicts the output power of Tm:YLF laser with respect to the incident pump power. The maximum output power was measured to be 61.0 W under incident pump power of 141.5 W, corresponding to a slope efficiency of 50.4% and an optical-to-optical conversion efficiency of 43.1%. The M^2 value of the Tm:YLF laser with two F–Ps was measured by 90/10 knife-edge technique at maximum output power, and we estimated the beam quality to be M^2 value $\sim$1.6. The dependence of laser wavelength on incident pump power was measured and is shown in Fig. 3. The shift of laser central wavelength was only 0.12 nm with the incident pump power from 24.5 W to 141.5 W.

4. Conclusion

In summary, a high power linewidth-narrowed diode-pumped Tm:YLF laser with two etalons has been demonstrated. Using two Tm:YLF crystals in a single folded cavity, 61.0 W of laser output at 1907.9 nm was obtained with a slope efficiency of 50.4%. Only 0.12 nm laser central wavelength shift was observed when the incident pump power increasing from 24.5 W to 141.5 W.

Acknowledgements

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