Diode-Pumped Single-Frequency Tm:YAG Laser with Double Etalons

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Abstract—A diode end-pumped single-frequency Tm:YAG laser at room temperature is reported. The maximal output power of single-frequency is as high as 60 mW by using two uncoated fused YAG etalons, which are respectively 0.1 and 1.0 mm thick. We obtained a single frequency Tm:YAG laser at 2013.91 nm. The change of the lasing wavelength on temperature was also measured. The single-longitudinal-mode laser can be used as a seed laser for coherent wind measurements and differential absorption LIDAR systems.

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1. INTRODUCTION

Solid-state lasers operating in the eye safe 2-µm spectral region have applications in a number of important areas [1–4]. Diode-pumped Tm, Ho co-doped laser crystal is excellent gain medium for generate 2 µm laser [5–9]. However, very strong cooperative up-conversion losses reduced the laser performance of Tm, Ho co-doped laser. In recent years, diode directly pumped Ho singly-doped lasers were reported [10], but the actual laser diode around at 1.9 µm circumscribed the laser performances of Ho crystal. Thulium has high absorption peaks conveniently located for diode pumping around 793 nm and it exhibits a cross-relaxation process which creates two ions in the upper laser level for each pump photon absorbed [11].

Some techniques have been used to obtain single-frequency lasers, such as microchip lasers, non-planar ring oscillators (NPRO), twisted-mode lasers and lasers inserted with etalon [12, 13]. Laser inserted with etalon is an ordinary method to obtain single-frequency operation, and it is easy to achieve single-frequency output power. Zhang et al. reported a single-longitudinal-mode Tm:Ho:YLF lasers by using double etalons at room temperature and the maximal output power was 118 mW [14]. Wu et al. reported single-longitudinal-mode Tm:YAG laser and Tm:LuAG laser by using double etalons at room temperature with the maximal output power were 75 mW at 2013.9 nm and 148 mW at 2026.4 nm, respectively [15, 16]. A diode-pumped Cr:Tm:Ho:YAG laser with double etalons operating had been demonstrated with a single-frequency output power [17].

YAG crystal has the advantages of high mechanical strength and large heat conductivity, which allows high-power operation with reduced risk of fracture [18–20]. In 1995, the experiment on the lasing performance of Tm:YAG microchip laser was carried out, and achieved 2 mW single mode oscillation at 263 K [21]. In 1998, 52 mW single frequency output used the cavity loss method were achieved by Matsuzaka and Hara [22]. In 1999, Svelto and Freitag demonstrated in a composite-cavity non-planar ring resonator of Tm:YAG laser firstly, with single frequency output power of 150 mW[23]. Then Zhang et al. achieved 514 mW single frequency output by using a twisted-mode cavity of Tm:YAG laser in 2010 [12].

In this letter, we report a single-frequency Tm:YAG laser under room temperature condition at 2013.91 nm with double Fabry–Perot etalons. An incident pump power of 2630 mW was used to generate the maximum single-frequency output power of 60 mW, corresponding to the optical conversion efficiency was 2.3% and the slope efficiency was 4.8%.

2. EXPERIMENTAL SETUP

Figure 1 shows the experimental setup. The Tm:YAG crystal is Ø3.0 × 2.5 mm rod, and the doped concentration of Tm³⁺ is 3.5%. The pumping side of the crystal is coated with a high transmission at 782 nm and high reflectivity at 2.01 µm. The opposite surface of the laser crystal is coated anti-reflection at 782-nm and 2.01 µm. The laser crystal is mounted in a copper heat sink maintained temperature of 292 K with thermoelectric cooler (TEC). The pumped source is a fiber coupled 5 W laser diode at wavelength of 792 nm. The pump-beam diameter is approximately 800 nm. The Tm:YAG laser resonator used is of plano-concave geometry. The output coupler is coated for 2% transmission at 2.1 µm with a 100 mm radius of curvature. The physical cavity length of Tm:YAG laser is approximately 40 mm. Two etalons (0.1 mm in thickness YAG and 1 mm in thickness YAG) with no coating were inserted in the cavity to restrict the wavelength of the Tm:YAG laser.

1 The article is published in the original.
Generally the first thin etalon equal to the system bandwidth can suppress all far modes oscillation. The second thick etalon then compresses the laser line-width further. When regulate the elevation angle of the two etalons carefully, the transmission ratio peak of two etalons can be adjusted consistently with the maximum value of the medium gain curve, then the laser can obtain the largest single-frequency output power oscillation with desired wavelength and narrow line-width.