



Original research article

High power acousto-optical Q-switched Tm:YLF-pumped Ho:GdVO₄ laser

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ABSTRACT

A high power acousto-optical Q-switched Ho:GdVO₄ laser at 2.05 μm pumped by a diode-pumped VBG-locked Tm:YLF laser at 1.94 μm is demonstrated in this paper. The maximum average output power of 10.3 W at pulse repetition rate of 10 kHz was obtained with the absorbed pump power of 34.9 W, corresponding to a slope efficiency of 36.8%. The minimum pulse width of 5.8 ns was obtained, corresponding to a peak power of 177.6 kW. The laser operated at a single mode (TEM₀₀) with a beam quality factor of M_x² of 1.3 and M_y² of 1.2 at maximum output level.

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1. Introduction

Pulsed solid-state lasers emitting in the nominally eye-safe 2 μm spectral region are very attractive for various technical applications in lidar, material processing, and mid-infrared generation via pumping optical parametric oscillators (OPOs) [1–3]. The rare-earth-ion thulium (Tm³⁺) and holmium (Ho³⁺) co-doping materials are commonly used to obtain the 2 μm laser. Unfortunately, due to the large upconversion loss and re-absorption loss, these lasers are difficult to achieve high performance at room temperature. In contrast, in-band pumping of the Ho system offers many advantages such as low quantum defect, low upconversion losses, and reduced sensitivity of gain versus temperature. In addition, Ho-doped solid-state lasers with long upper laser level lifetime are particularly attractive for Q-switched operation.

Among numerous hosts, gadolinium vanadate (GdVO₄) crystals doped with various ions represent a promising new material for diode-pumped Tm and Tm, Ho co-doped lasers. The GdVO₄ crystal has a large thermal conductivity (11.7 W/mK) which makes it favorable to cool the crystal efficiently. The thermal conductivity of GdVO₄ is more than a factor of two higher than that of YVO₄ and is even higher than that of YAG. Recently, continuous wave (CW) and Q-switched laser performances of Tm:GdVO₄ and Tm, Ho:GdVO₄ crystals were widely investigated [4–7]. For singly Ho:GdVO₄ lasers, using a Tm-fiber laser as the pump source, our group developed the its output power as high as 10 W-level [8,9]. However, the Tm-fiber with free polarization was used in above works, the output power of Ho:GdVO₄ laser is fluctuated wildly, which caused by polarization change of Tm-fiber when fiber is moving.

In this paper, we used a diode-pumped VBG-locked Tm:YLF laser with linear polarization as the pump source, investigated the room temperature CW and actively Q-switched performances of Ho:GdVO₄ laser. When the absorbed pump power is 34.9 W, the maximum output power of 11.5 W and 10.3 W were obtained with CW and Q-switched mode, respectively. At

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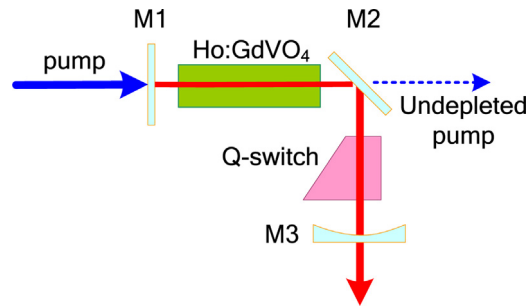


Fig. 1. Diagram of the experimental setup.

the repetition rate of 10 kHz, the minimum pulse width of 5.8 ns was obtained, corresponding to a peak power of 177.6 kW. The output beam had quality of M^2 factor with M_x^2 of 1.3 and M_y^2 of 1.2 at maximum output level.

2. Experimental setup

The experimental setup is schematically shown in Fig. 1. The dimension of *a*-cut Ho:GdVO₄ crystal with doped concentration of 1.0 at.% is 4 mm × 4 mm (in cross section) × 20 mm (in length). The two end faces of the crystal were antireflection coated at both pump wavelength of 1.94 μm ($R < 0.5\%$) and lasing wavelength of 2 μm ($R < 0.3\%$). The Ho:GdVO₄ crystal was sandwiched between two water-cooled copper heat sinks using 0.1-mm-thick indium foil. The temperature of the cooling water for the laser crystal is controlled at 20 °C. A homemade diode-pumped VBG-locked Tm:YLF laser with output power of 50 W was used as the pump source. Its output wavelength and linewidth are 1940 nm and 0.2 nm, respectively. The pump beam diameter was measured to be 500 μm in the Ho:GdVO₄ crystal. We also measured that the single-pass absorptions of Ho:GdVO₄ crystal is 74% at pump wavelength.

A L-shaped resonator with physical cavity length of about 100 mm was used for the Ho:GdVO₄ laser. The cavity mirror M1 was flat with high reflectivity at 2 μm and high transmission at 1.94 μm. The flat 45° dichroic mirror M2 had high transmission for the pump light and high reflectivity at 2 μm. The output coupling M3 was plane-concave with the radius of curvature of 200 mm and transmittance of 40%. An AR-coated quartz acousto-optic (AO) switch (Model: QSG41-2) with acoustic aperture of 1.1 mm was used for Q-switched operation. The length of Q-switch crystal was 35 mm. The radio frequency (RF) was 41 MHz, and the RF power was 20 W. The modulation loss is greater than 45%, which is adequate to hold off the laser actions.

3. Experimental results and discussion

Firstly, we investigated the CW output performance of Ho:GdVO₄ laser, as shown in Fig. 2. The threshold pump power was 6.78 W. The maximum output power of 11.5 W was obtained with absorbed pump power of 34.9 W. With respect to the absorbed pump power, the slope efficiency was 40.2%, corresponding to the optical-to-optical efficiency of 33.0%. Secondly, in the case of Q-switched mode, at the pulse repetition rate of 10 kHz, the maximum average output power 10.3 W was achieved at same pump power, corresponding to the slope efficiency of 36.8% and optical-to-optical efficiency of 29.5%. The output spectrum of CW Ho:GdVO₄ laser was measured by a wavemeter (Bristol 721A), as shown in Fig. 2. The output wavelength was centered at 2047.9 nm. The full width at half-maximum linewidth was 0.2 nm.

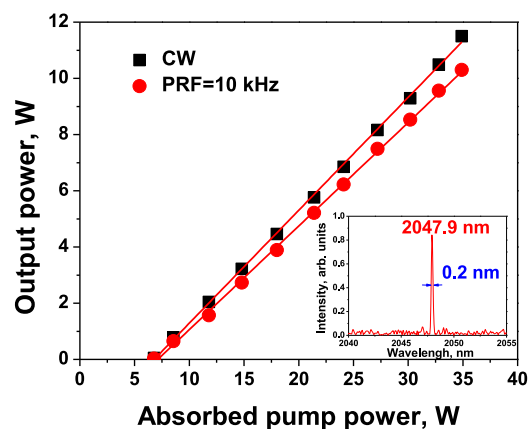


Fig. 2. The output characteristics of Ho:GdVO₄ laser. Insert, the output spectrum of CW Ho:GdVO₄ laser.

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