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Efficient passively Q-switched operation of a diode-pumped Nd:GGG laser with a Cr^{4+}:YAG saturable absorber

Chun-Hua Zuo, Jing-Liang He *, Hai-Tao Huang, Bai-Tao Zhang, Zhi-Tai Jia, Chun-Ming Dong, Xu-Tang Tao

State Key Laboratory of Crystal Materials and Institute of Crystal Materials, Shandong University, Jinan 250100, China

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ABSTRACT

The continuous-wave (cw) and passive Q-switching operation of a diode-end-pumped gadolinium gallium garnet doped with neodymium (Nd:GGG) laser at 1062 nm was realized. A maximum cw output power of 6.9 W was obtained. The corresponding optical conversion efficiency was 50.9%, and the slope efficiency was determined to be 51.4%. By using Cr^{4+}:YAG crystals as saturable absorbers, Q-switching pulse with average output power of 1.28 W, pulse width of 4 ns and repetition rate of 6.2 kHz were obtained. The single-pulse energy and peak power were estimated to be 206 μJ and 51.6 kW, respectively. The conversion efficiency of the output power from cw to Q-switching operation was as high as 84.7%.

1. Introduction

Pulse width below 10 ns with peak power exceeding 50 kW make neodymium-doped laser materials coherent sources that are interesting for a variety of applications, such as laser detection, lidar and in nonlinear frequency conversion [1]. Many neodymium-doped laser materials, such as Nd:YAG, $Nd:YVO_4$ and $Nd:GdVO_4$, have achieved successful Q-switching by using Cr^{4+}:YAG crystal as the saturable absorber. The corresponding pulse widths were 2.3, 0.85 and 8.8 ns, respectively [2–4]. Besides the above laser crystals, there were other crystals that were attractive candidates for compact passive Q-switched diode-pumped laser and had potential to make effective microchip laser. One example was the gadolinium gallium garnet doped with neodymium (Nd:GGG). The fluorescent lifetime and stimulated-emission cross-section of Nd:GGG were estimated to be 265 μs and $2.1\times10^{-19}\,cm^2$, respectively [5], which were beneficial for achieving efficient passive Q-switching. Nd:GGG was usually used in the solid state heat capacity laser (SSHCL) because of its available large size and high optical quality [6,7]. Characterizations of diode-pumped Nd:GGG in continuous-wave (cw) regimes had been reported before[8]. In this paper, by using Nd:GGG as the active medium, using different combinations of Cr^{4+}:YAG saturable absorbers and output couplers, we set up efficient passively Q-switched laser configurations. A pulse width of 4 ns and a peak power of 51.6 kW were obtained. Furthermore, up to 84.7% of the cw power was converted into pulsed power. This is much higher than others previously reported in the literatures [2–4,9–13].

2. Experimental details

The cw and passive Q-switching operation were all carried out in the plano-concave resonator shown in Fig. 1. M_1 is a concave mirror with radius of curvature of 100 mm, antireflectance coated at 808 nm on the entrance face, high reflectance coated at 1062 nm and high transmission coated at 808 nm on the other face. M_2 is a flat mirror with transmissions of 5%, 10% and 27% at 1062 nm and was employed as the output coupler. The Nd:GGG crystal used was 1 at%, cut along the direction of [111], with dimensions of $4\times4\times8\,mm^3$, and was high transmission coated at 808 and 1062 nm on both sides. The laser crystal was wrapped with indium foil and held in an aluminium block that was cooled by water at the temperature of 20 °C. The pump source was a fibre-coupled LD with a diameter of 400 μm and a numerical aperture of 0.22. Its radiation was coupled into the laser crystal by

* Corresponding author.
E-mail address: jlhe@icm.sdu.edu.cn (J.-L. He).

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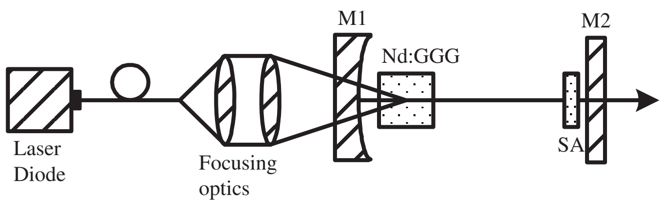

Fig. 1. Configuration of the cw and pulsed laser output.

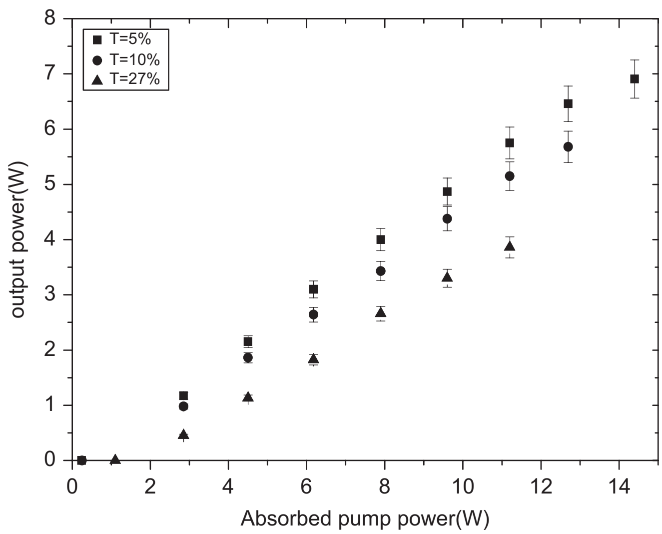

Fig. 2. Cw output power versus absorbed power for different output couplers.

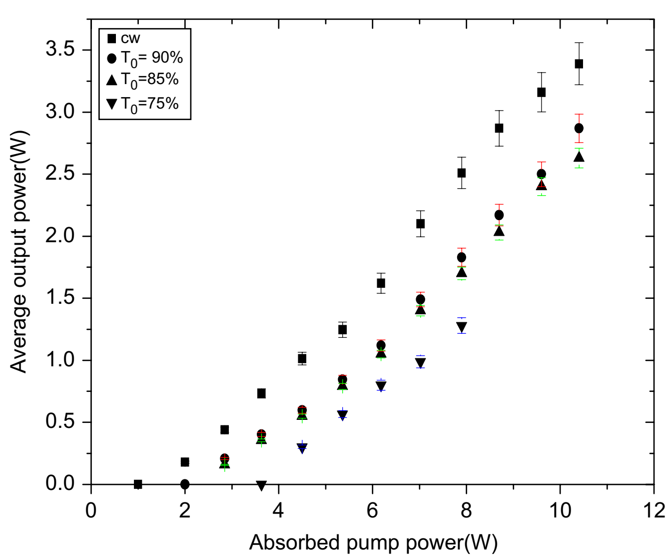

Fig. 3. Q-swiched average output power versus absorbed power for different initial transmissions.

a focusing optical system. The beam spot radius generated within the crystal was estimated to be 200 μm. In the Q-switching experiment, the cavity length was tuned to be 30 mm. Three Cr^{4+}:YAG samples were used as saturable absorbers with the initial transmissions of 90%, 85% and 70%. Their end faces were antireflectance coated at 1062 nm. Cr^{4+}:YAG was held in an aluminium block and placed close to M_2. It was not actively cooled in the experiment. Both Nd:GGG and Cr^{4+}:YAG were

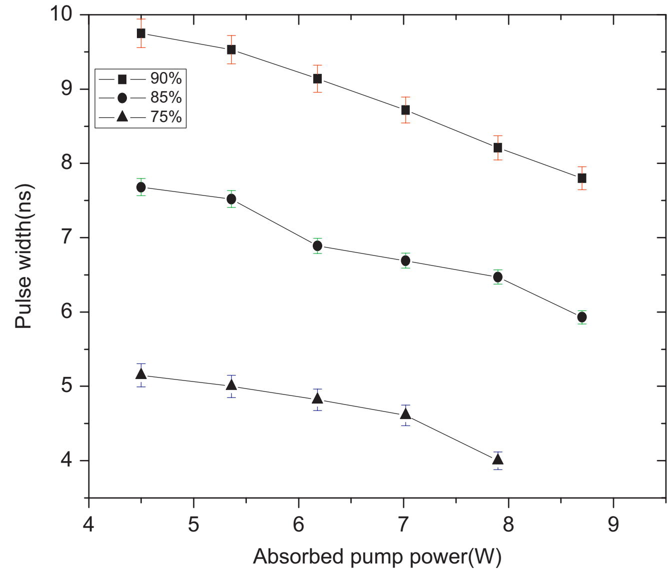

Fig. 4. Pulse width versus the absorbed power.

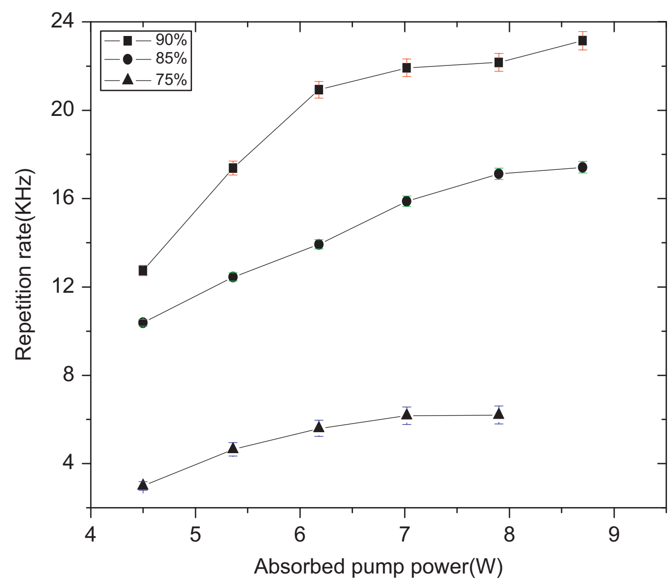

Fig. 5. Pulse repetition rate versus the absorbed power.

manufactured by the Institute of Crystal Materials, Shandong University, China. The laser pulse signal was monitored and measured by a 1 GHz oscilloscope (Tektronix Dpo7104) and a photodetector (New focus, model 1611).

3. Results and discussion

Fig. 2 shows the cw output characterizations of Nd:GGG laser at 1062 nm using different output couplers ($T = 5\%$, 10% and 27% at 1062 nm). The length of the cavity was 30 mm. When output couplers of 5%, 10% and 27% were used, the corresponding threshold pump power was measured to be 0.22, 0.25 and 1.1 W, respectively. Under the absorbed pump power of 14.4, 12.7 and 11.2 W, the highest output power was 6.91, 5.68, and 3.86 W, respectively. The optimal performance was obtained with an output coupling of $T = 5\%$, and the maximum optical conversion efficiency and slope efficiency were 50.9% and 51.4%, respectively.