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DIODE-PUMPED ACOUSTO-OPTICALLY *Q*-SWITCHED LASER USING A NOVEL Nd:GdYTaO_4 MIXED CRYSTAL

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Abstract

We demonstrate a diode-pumped acousto-optically (A-O) *Q*-switched 1,066 nm laser with a novel Nd:$Gd_{0.69}Y_{0.3}TaO_4$ mixed crystal. At a modulation repetition rate of 10 kHz and an absorbed pump power of 15 W, the pulsed laser output characteristics are: average output power 2.41 W, pulse width 27.2 ns, pulse energy 241 μJ, and pulse peak power 8.86 kW. At a modulation repetition rate of 20 kHz and an absorbed pump power of 15 W, the characteristics are: average output power 2.68 W, pulse width 30.1 ns, pulse energy 134 μJ, and pulse peak power 4.45 kW.

Keywords: mixed crystal, Nd:$Gd_{0.69}Y_{0.3}TaO_4$, acousto-optical *Q*-switched pulsed laser.

1. Introduction

Diode-pumped all-solid-state 1.06 μm lasers with high repetition rates are widely used in many applications such as laser remote sensing, laser processing, and laser diagnostics [1–7]. Neodymium ion-hosted crystals, such as Nd:YAG, have been widely employed to construct laser-diode-pumped solid-state lasers in the near-infrared region with the merits of low cost, high efficiency, and compactness [8–11]. However, due to the narrow absorption bandwidth of 1.5 nm at 808 nm absorption line [12], Nd:YAG crystal is sensitive to the pumping wavelength. Recently, in 2015, Nd^{3+}-doped tantalates of Nd:$GdTaO_4$ single crystals and Nd:$Gd_xY_{1-x}TaO_4$ mixed single crystals, in which the Gd ions were replaced by Y ions, were successfully grown by the Czochralski method, and the spectroscopic properties were investigated [13, 14]. Compared to Nd:YAG crystals, the absorption bandwidth at 808 nm for a-cut Nd:$GdTaO_4$ and Nd:$Gd_{0.69}Y_{0.3}TaO_4$ is equal to 6 and 8 nm, respectively. Therefore, Nd:$GdTaO_4$ and Nd:$Gd_xY_{1-x}TaO_4$ crystals are favorable for reducing the demands of pumping source and improving laser efficiency. Furthermore, the upper-level lifetimes of Nd:$GdTaO_4$ (178 μs) and Nd:$Gd_{0.69}Y_{0.3}TaO_4$ (182 μs) are smaller than that of Nd:YAG (230 μs) [12–14], and this is beneficial for producing high-repetition-rate lasers. Compared to nonmixed

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crystals, it is believed that the characteristics of mixed crystals, such as the reduced stimulated emission cross section and the increased higher specific heat, are changed [15, 16]. Due to these merits of mixed crystals, the actively Q-switched Nd:$Gd_xY_{1-x}TaO_4$ laser is promising.

In this paper, we demonstrate an acousto-optically (A-O) Q-switched 1,066 nm laser with a novel Nd:$Gd_{0.69}Y_{0.3}TaO_4$ mixed crystal. The pulsed Nd:$Gd_{0.69}Y_{0.3}TaO_4$ laser performance is investigated when different modulation repetition rates of A-O Q-switch are used.

2. Experimental Setup

The experimental setup of an acousto-optically Q-switched Nd:$Gd_{0.69}Y_{0.3}TaO_4$ laser under 808 nm laser-diode end pumping is shown in Fig. 1, where L1 and L2 are a pair of plano-convex lens used for pumping, laser beam collimating, and focusing. An a-cut Nd:$Gd_{0.69}Y_{0.3}TaO_4$ mixed crystal is used as the laser medium. The dimensions of this a-cut Nd:$Gd_{0.69}Y_{0.3}TaO_4$ mixed crystal are $2\times2\times5$ mm^3. The Nd^{3+} doping concentration is 1 at.%. The crystal is wrapped into indium foil and placed in a water-cooled copper heat sink with microchannel structure. Here, M1 is a flat mirror with antireflection at 808 nm and high reflectivity at 1.06 μm. The output coupler M2 has transmission (T) of 5%. The A-O Q-switch has antireflection at 1.06 μm on both sides.

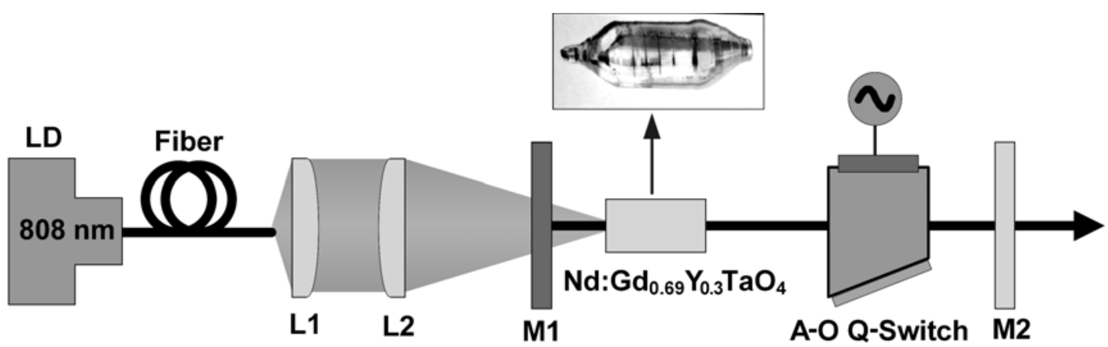

Fig. 1. Schematic of an acousto-optically Q-switched Nd:$Gd_{0.69}Y_{0.3}TaO_4$ laser.

3. Results and Discussions

We investigated the pulsed Nd:$Gd_{0.69}Y_{0.3}TaO_4$laser performance at different repetition rates (f) of A-O Q-switching. The average output power as a function of absorbed incident pump power at two repetition rates of 10 and 20 kHz is shown in Fig. 2. We can see that the average output power increases with the absorbed incident pump power; also the output power for $f = 20$ kHz was higher than that of $f = 10$ kHz. When the absorbed incident pump power was 15 W, the output power was 2.41 and 2.68 W for repetition rates of 10 and 20 kHz, respectively.

Using a high-speed Si-detector, we measured simultaneously the pulse width shown in Fig. 3. The pulse width decreases when the absorbed incident pump power increases. At an absorbed incident pump power of 15 W, the pulse width was 27.2 and 30.1 ns for a repetition rate of 10 and 20 kHz, respectively.

The results of calculations of the pulse energy and pulse power for Nd:$Gd_{0.69}Y_{0.3}TaO_4$ laser are given in Figs. 4 and 5, respectively. The pulse energy and power increase when the absorbed incident pump power increases. We observed that the pulse energy and pulse power at $f = 10$ kHz were higher than

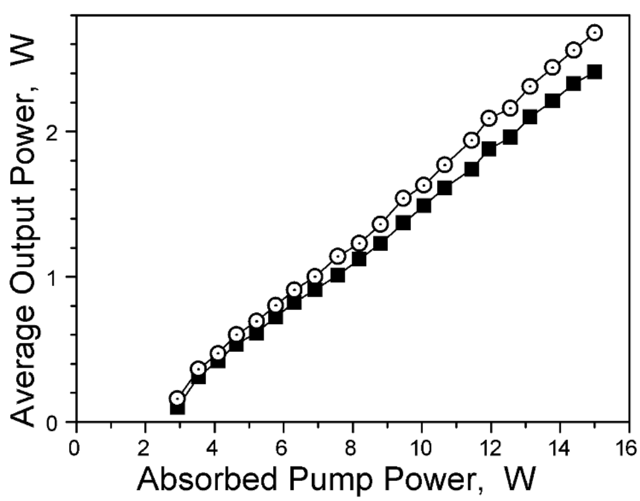

Fig. 2. Average output power as a function of absorbed incident pump power at a a modulation repetition rate of 10 kHz (■) and 20 kHz (⊙).

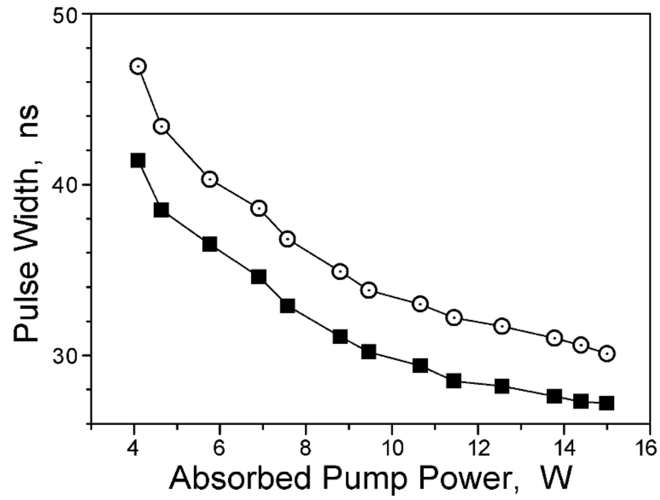

Fig. 3. Pulse width as a function of absorbed incident pump power at a a modulation repetition rate of 10 kHz (■) and 20 kHz (⊙).

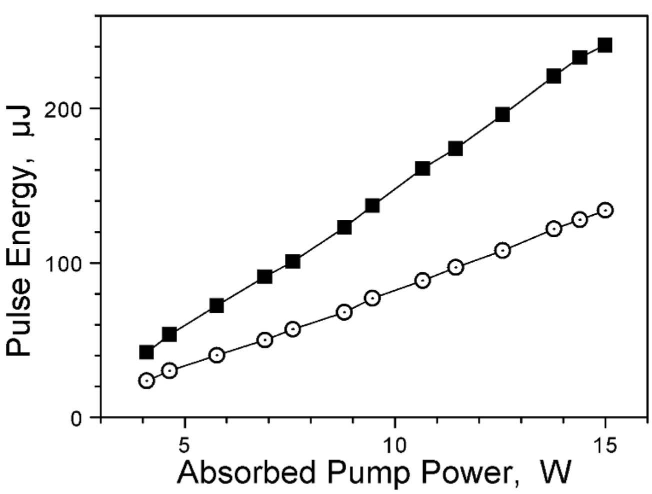

Fig. 4. Pulse energy as a function of absorbed incident pump power at a modulation repetition rate of 10 kHz (■) and 20 kHz (⊙).

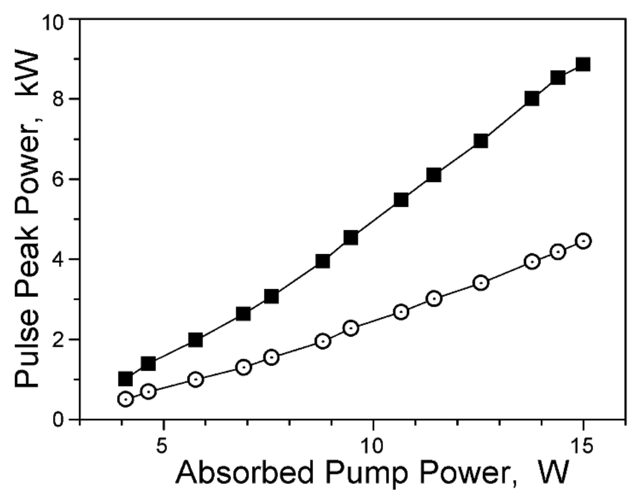

Fig. 5. Pulse power as a function of absorbed incident pump power at a modulation repetition rate of 10 kHz (■) and 20 kHz (⊙).

those at $f = 20$ kHz. At an absorbed incident pump power of 15 W, we obtained a pulse energy of 241 μJ and a pulse power of 8.86 kW at $f = 10$ kHz; these characteristics are obviously better than those of 134 μJ and 4.45 kW for $f = 20$ kHz.

4. Summary

In conclusion, we demonstrated a diode-pumped acousto-optically Q-switched 1,066 nm laser with a novel Nd:$Gd_{0.69}Y_{0.3}TaO_4$ mixed crystal. Two repetition rates of 10 and 20 kHz of acousto-optically Q-switching were used to modulate the laser. At an absorbed incident pump power of 15 W and a repetition rate of 10 kHz, we report the pulsed laser output characteristics at an average output power of 2.41 W, a pulse width of 27.2 ns, a pulse energy of 241 μJ, and a pulse power of 8.86 kW. At a repetition rate of 20 kHz, the results are 2.68 W, 30.1 ns, 134 μJ, and 4.45 kW, respectively. We believe that the laser performance can be further improved significantly if a Nd:$GdYTaO_4$ mixed crystal with better quality is used.

Acknowledgments

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