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A DOUBLY Q-SWITCHED Nd:GdYTaO$_4$ LASER

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Abstract

In this letter, we demonstrate for the first time a doubly Q-switched 1,066 nm pulsed laser using a novel Nd:Gd$_{0.69}$Y$_{0.3}$TaO$_4$ mixed crystal. Compared to purely acousto-optical (AO) Q-switched, the simultaneous use of AO Q-switch and Cr^{4+}:YAG saturable absorber can provide the generation of shorter pulses. We investigate the pulsed laser performance at two modulated repetition rates of 10 and 20 kHz.

Keywords: mixed crystal, Nd:Gd$_{0.69}$Y$_{0.3}$TaO$_4$, acousto-optical Q switching, doubly Q switching, pulse width.

1. Introduction

Pulsed lasers with high repetition rates emitting at different wavelengths are widely used in various applications [1–8]. The acousto-optical (AO) Q switch has been adopted in actively Q-switched lasers because of its simplicity, compactness, and high efficiency. It can provide a stable pulse-train output with narrow pulse width. Using both an active Q switch and a passive Q-switch saturable absorber in the cavity simultaneously, the laser can provide a shorter pulse when compared with a single active Q switch. In this doubly Q-switched laser, the active Q switch is used to control the pulse repetition rate and, at the same time, it allows the laser media to store energy to ensure that the population inversion is fully

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saturated, while the passive Q-switch saturable absorber is used to generate symmetric short laser pulses through the normal saturable absorption characteristics [9–12]. Doubly Q-switched lasers with active modulator and passive saturable absorber have been reported in [13–15].

Recently, in 2015, the Nd^{3+}-doped tantalate of a Nd:$Gd_xY_{1-x}TaO_4$ mixed crystal was grown successfully by the Czochralski method, in which the Gd ions were partly replaced by Y ions [16]. The absorption bandwidth at 808 nm for a-cut Nd:$Gd_{0.69}Y_{0.3}TaO_4$ was as wide as 8 nm. Therefore, with its broad absorption band, the Nd:$Gd_xY_{1-x}TaO_4$ mixed crystal is favorable for reducing the demands of pumping source and improving laser efficiency. To date, there are few publications concerning the Nd:$GdYTaO_4$ laser. A maximum continuous wave output power of 6.37 W for the Nd:$Gd_{0.69}Y_{0.3}TaO_4$ laser was obtained at an absorbed pump power of 20 W [17]. A purely AO Q-switched Nd:$Gd_{0.69}Y_{0.3}TaO_4$ laser with a maximum repetition rate of 20 kHz was reported in [18]. The obtained pulse width, pulse energy, and pulse peak power were 30.1 ns. 134 μJ, and 4.45 kW, respectively.

In this paper, we demonstrate for the first time a doubly Q-switched 1,066 nm pulsed lasers using a novel Nd:$Gd_{0.69}Y_{0.3}TaO_4$ mixed crystal. By employing an AO modulator and Cr^{4+}:YAG saturable absorber, the pulsed laser performances were investigated.

2. Experimental Setup

The experimental configuration of the doubly Q-switched Nd:$Gd_{0.69}Y_{0.3}TaO_4$ laser under 808 nm laser-diode end-pumping is shown in Fig. 1.

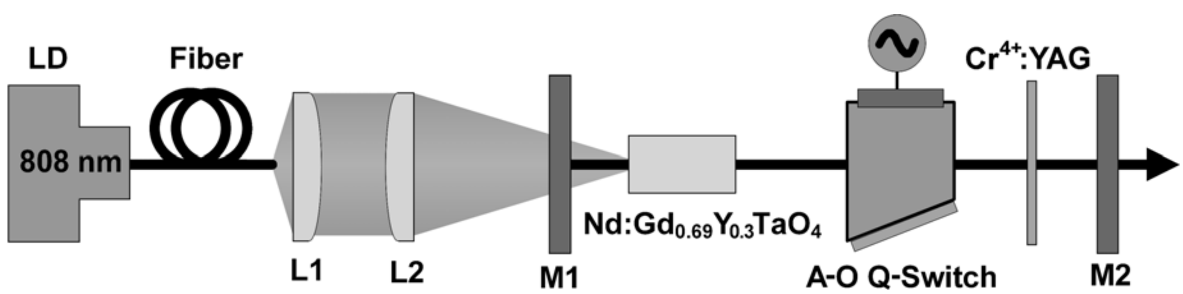

Fig. 1. Schematic of the doubly Q-switched Nd:$Gd_{0.69}Y_{0.3}TaO_4$ laser.

The 808 nm pumping source employed in experiments was a fiber-coupled laser diode. The fiber had a core diameter of 400 μm and a numerical aperture of 0.22. The output beam was reshaped using a set of collimating and focusing lenses L_1 and L_2. The a-cut Nd:$Gd_{0.69}Y_{0.3}TaO_4$ mixed crystal was 2.0, 2.0, and 5.0 mm in width, height, and length, respectively. The Nd^{3+}-doping concentration was 1 at%. The laser cavity was constructed by two plano–plano mirrors. The input mirror M_1 was coated, providing antireflection at 808 nm and high reflectivity at the 1.06 μm. The output coupler M_2 had a transmissivity T of 5% at 1.06 μm. The Cr^{4+}:YAG saturable absorber with initial transmissions of 90% was chosen.

3. Results and Discussions

The pulsed Nd:$Gd_{0.69}Y_{0.3}TaO_4$ laser performance was investigated at different repetition rates f of AO switching. The average output power of AO Q-switched and doubly Q-switched Nd:$Gd_{0.69}Y_{0.3}TaO_4$ lasers 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 from this figure that the average output power increases with the absorbed incident pump power, and the output power for $f = 20$ kHz was higher than that for $f = 10$ kHz. Due to the absorption loss of Cr^{4+}:YAG crystal, the average output power of the doubly Q-switched laser was smaller than that of a purely AO Q-switched one. When the absorbed incident pump power was 15 W, the maximum average output power was 2.41 and 2.68 W for the purely AO Q-switched laser at repetition rates of 10 and 20 kHz, respectively. Those values for the doubly Q-switched laser were 1.61 and 1.77 W, respectively.

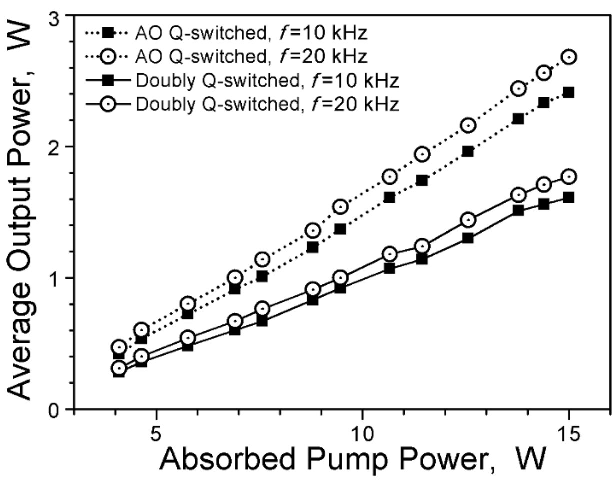

Fig. 2. Average output power as a function of absorbed incident pump power.

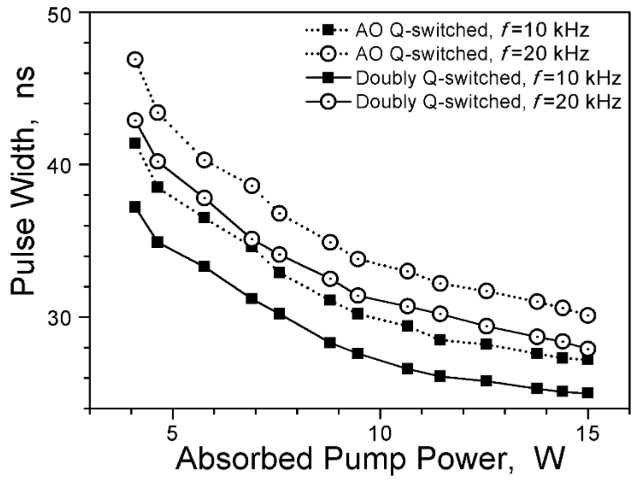

Fig. 3. Pulse width as a function of absorbed incident pump power.

The pulse width at repetition rates of 10 and 20 kHz as a function of absorbed pump power is shown in Fig. 3. Due to the saturable absorption characteristics, the pulse width of the doubly Q-switched lasers was narrower than that of the purely AO Q-switched lasers, especially when the absorbed pump power was low. For example, when the absorbed pump power was 4.1 W and the repetition rate was 10 kHz, the pulse width was 41.4 ns for AO Q-switched lasers and 37.23 ns for doubly Q-switched lasers.

The calculated results of pulse energy and pulse peak power for AO Q-switched and doubly Q-switched Nd:$Gd_{0.69}Y_{0.3}TaO_4$ lasers are shown in Fig. 4 and 5, respectively. The pulse energy and pulse peak power increased when the absorbed incident pump power increased. The pulse energy and pulse peak power at $f = 10$ kHz were higher than those of 20 kHz for the AO Q-switched laser and doubly Q-switched laser, respectively. Although the pulse width of the doubly Q-switched laser was shorter than that of the AO Q-switched laser, the pulse peak power decreased. At an absorbed incident pump power of 15 W, the pulse energy for the AO Q-switched and doubly Q-switched Nd:$Gd_{0.69}Y_{0.3}TaO_4$ lasers at $f = 10$ kHz were 241 and 161 μJ, respectively. For $f = 20$ kHz, those were 134 and 88.5 μJ, respectively. The pulse peak power for AO Q-switched and doubly Q-switched Nd:$Gd_{0.69}Y_{0.3}TaO_4$ lasers at $f = 10$ kHz were 8.86 and 6.44 kW, respectively. For $f = 20$ kHz, those were 4.45 and 3.17 kW, respectively.

4. Summary

In conclusion, we demonstrated a doubly Q-switched laser using a novel Nd:$Gd_{0.69}Y_{0.3}TaO_4$ mixed crystal for the first time. The laser performances were investigated at two modulated repetition rates of

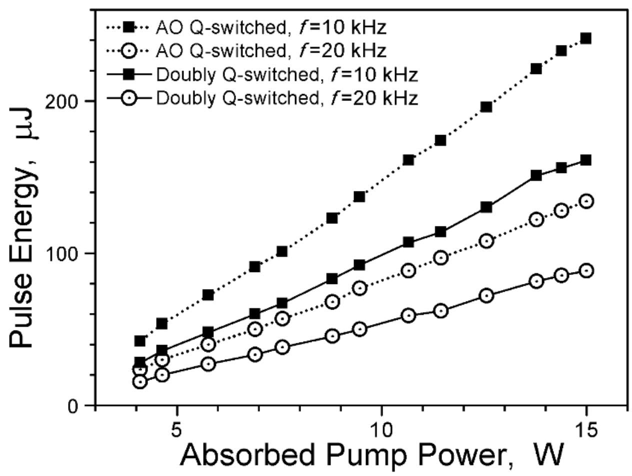

Fig. 4. Pulse energy as a function of absorbed incident pump power.

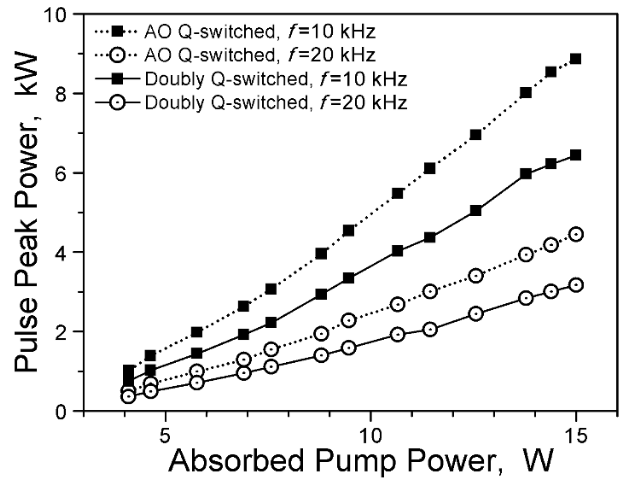

Fig. 5. Pulse peak power as a function of absorbed incident pump power.

10 and 20 kHz. Due to the saturable absorption characteristics of Cr^{4+}:YAG, compared to the AO Q-switched laser, the doubly Q-switched system can generate shorter pulses, especially when the absorbed pump power was low. At an absorbed incident pump power of 15 W and a repetition rate of 10 kHz, the pulsed laser output characteristics of average output power, pulse width, pulse energy, and pulse peak power for AO Q-switched laser and doubly Q-switched Nd:$Gd_{0.69}Y_{0.3}TaO_4$ lasers were 2.41 and 1.61 W, 27.2 and 25.0 ns, 241 and 161 μJ, and 8.86 and 6.44 kW, respectively.

Acknowledgments

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