Experimental study of acousto-optic Q-switched Nd:CTGS laser

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We have relized a laser diode-end pumped acousto-optic Q-switched laser with a Nd:CTGS crystal. Stable actively Q-switched laser was obtained at wavelength of 1065 nm. Under an absorbed pump power of 14.5W, an actively Q-switched laser with average output power of 894 mW was obtained at the repetition rate of 15 kHz. When the repetition rate was 5 kHz, an actively Q-switched laser with the minimum pulse width of 38 ns, the peak output power of 3.07 kW, and the pulse energy of 110.6 μJ was demonstrated.

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Keywords: Nd:CTGS crystal, Actively Q-switched, Laser diode end-pumped

1. Introduction

Recent years, all solid state pulsed lasers have been demonstrated widely used in industry, military, medical, and other fields due to their advantages of simple construction, high stability, high efficiency and so on. So far, to explore novel high-quality laser crystal has become more and more important for the development of all solid state lasers. Many Nd-doped crystals have been proved to be excellent crystal materials for diode pumped all solid state lasers [1-6].

As a multi-functional crystal, Ca3TaGa3Si2O14 (CTGS) crystals have been intensively investigated in recent years for their excellent dielectric and piezoelectric properties [7-14]. Recently, many researchers proved that CTGS can also be used as a host material doped rare-earth ion, such as Nd^{3+} [15-18] and Yb^{3+} [19, 20] for nonlinear or laser applications. Nd^{3+} doped CTGS (Nd:CTGS) crystals have been studied for self-frequency-doubling (SFD) applications. A SFD green laser power of 71.58 mW at 533 nm was achieved by Nd:CTGS crystal [16]. Furthermore, 1 kW peak power SFD microchip green laser was realized by passively Q-switching operation with Nd:CTGS/Cr:YAG crystal [17].

The continuous wave (CW) and passive Q-switching laser performance of laser diode end-pumped Nd:CTGS crystal have also been investigated. A 1065 nm passively Q-switched Nd:CTGS laser with an energy of 45.7 μJ, repetition frequency of 33.1 kHz and duration of 8.4 ns have been obtained by using Cr:YAG crystal as saturable absorber [18]. It is well known that acousto-optic Q-switching is a reliable technique for generating stable pulse trains with small pulse widths and large peak powers. However, there was no any report about the acousto-optic Q-switching performance of Nd:CTGS laser.

In this paper, we explored the performance of acousto-optic Q-switched Nd:CTGS laser intensively. The Q-switched laser oscillated at wavelength about 1065 nm was found. Under the pump power of 14.5 W, the maximum average output power of 894 mW was obtained at repetition rate of 15 kHz. The maximum peak power and the maximum pulse energy were calculated to be 3.07 kW and 110.6 uJ respectively at the repetition rate of 5 kHz, while the minimum pulse width was 38 ns.

2. Experimental setup

Fig. 1 showed the experimental setup for the laser diode end-pumped actively Q-switched Nd:CTGS laser. The pump source was a commercial fiber coupled laser diode emitting at 808 nm. Its radiation was coupled into the laser crystal by a coupling system with a numerical aperture (N.A.) of 0.22. The laser cavity consists an input mirror M_1, an output mirror M_2, a Nd:CTGS crystal, and a 30-mm-long acousto-optic Q switch, which was driven at a 27 MHz center frequency by 50 W of RF power. M_1 was a plano-concave mirror with a curvature radius of 300 mm. The plane face was anti-reflection at 808 nm (R<0.2%), the concave face was coated for high transmission at 808 nm (R<3%) and high reflection at 1064 nm (R>99.8%). The output mirror M_2 was coated with partial transmission (Toc=5%) at 1064 nm. The overall laser cavity length was 70 mm. The laser crystal Nd:CTGS was a-cut and with dimensions of 3×3×7 mm^3. The laser crystal was wrapped with indium and mounted in a copper block cooled by water at 18 ºC. The laser pulse signal was detected by a digital oscilloscope (DSO6052A, Agilent) and a photo-detector (New Focus, model 1611). The average output power was recorded by a laser power meter (Fieldmax-II, Coherent). The laser spectra were measured by an optical spectrum analyzer (AQ6370D).

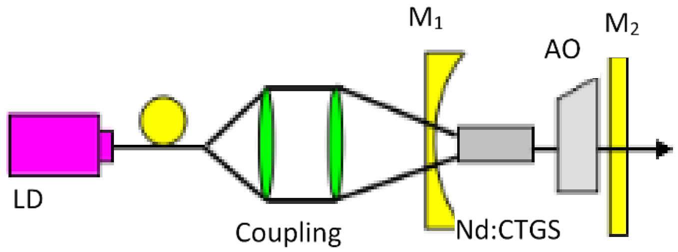

Fig. 1. The experimental set up for AO Q-switched Nd:CTGS laser (color online)

3. Results and discussion

First, the performance of CW operating of Nd:CTGS was examined. The threshold pump power of the CW laser operation was measured to be 3.5W. The highest continuous laser output power was 1.28W，the slope efficiency and the optical conversion efficiency were 10.2% and 8.8% respectively. Because the Nd:CTGS crystal contains some impurities and defects, which leads to the high optical loss of the crystal, the slope efficiency was really low. When optical quality of the Nd:CTGS crystal is further improved by optimizing the growth technology, the laser performance may be enhanced. Furthermore, the crystal was un-coated. If the crystal had been antireflective coated at 1065 nm and high transmittance coated at 808 nm on the two end faces, the energy conversion efficiency from pump source to output power may be optimized.

Fig. 2 showed the spectra of the acousto-optic Q-switched Nd:CTGS laser obtained under the absorbed pump power of 10W. It can be seen that the output laser operated at wavelength of 1065 nm. The full width at half-maximum (FWHM) of the spectra was 1.4 nm.

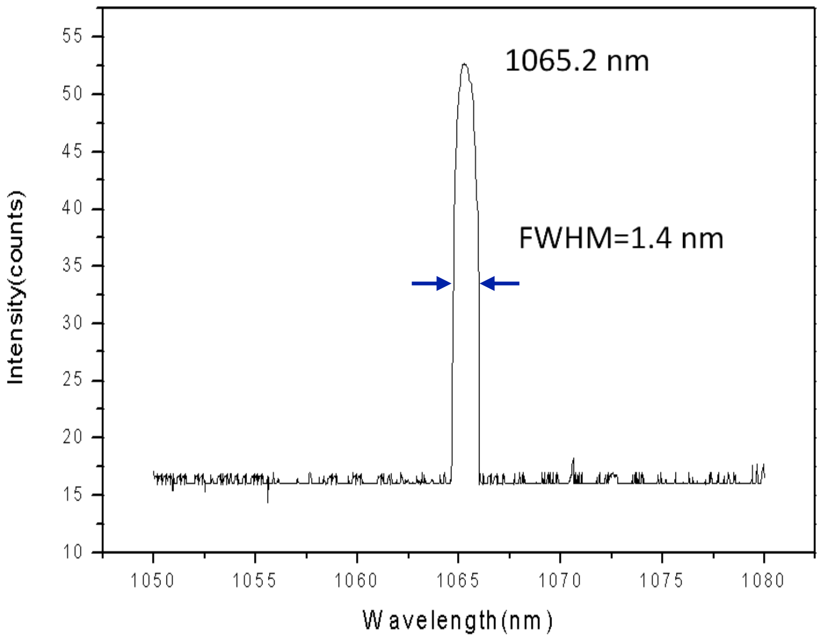

Fig. 2. The spectra of AO Q-switched Nd:CTGS laser (color online)

The variation of the average output power of acousto-optic Q-switched Nd:CTGS laser with absorbed pump power was shown in Fig. 3. The pulse repetition rate of acousto-optic Q-switch was 5 kHz, 10 kHz and 15 kHz respectively. The continuous laser operation was shown in the same figure in order to be convenient for comparison. Under the absorbed pump power of 14.5 W, the maximum acousto-optic Q-switched average output power was 894 mW at a pulse repetition rate of 15 kHz. The corresponding maximum conversion efficiency from CW to Q-switching operation were 69%. When the pulse repetition rates were 5 kHz and 10 kHz, the maximum Q-switched average output power was 553 mW and 703 mW respectively, and the corresponding conversion efficiency from CW to Q-switching operation was 43% and 54% respectively.

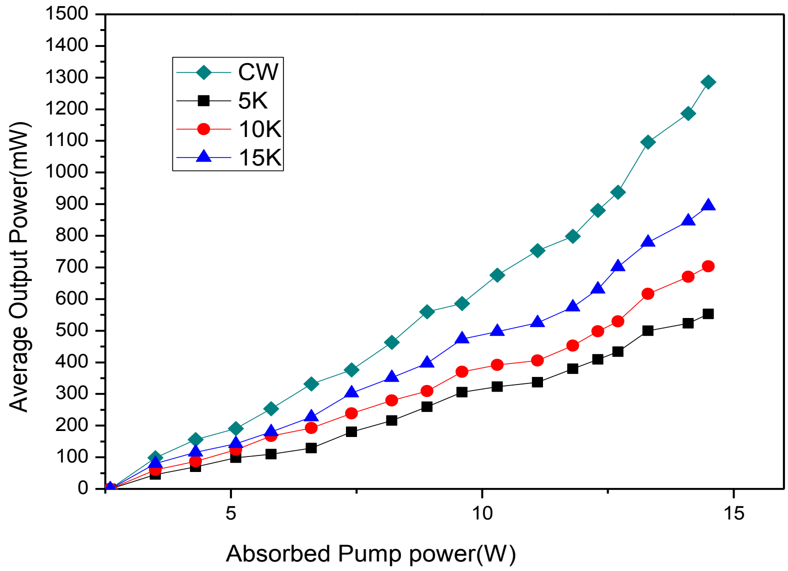

Fig. 3. The variation of average output power with absorbed pump power for AO Q-switched Nd:CTGS laser (color online)

Fig. 4 showed the pulse width varying with the increase of the pump power at different repetition rates. It can be seen that the pulse width decreased with the rising of the pump power at the same repetition rate. By using the formulas $E=P_{av}/F$ and $P_{peak}=E/t_p$,(E was the pulse energy, P_{av} was the average Q-switched output power, F was the repetition rate, P_{peak} was the peak power, t_p was the pulse width), the pulse energy and the peak power could be calculated.

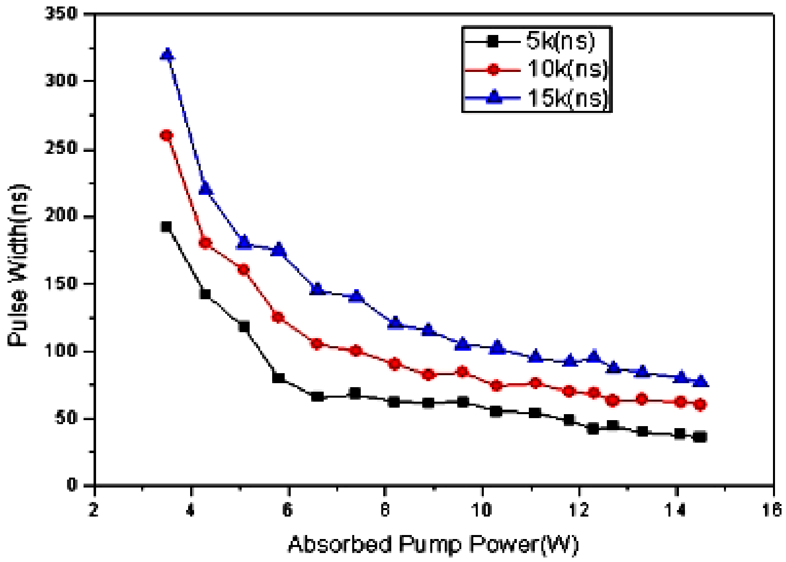

Fig. 4. The variation of pulse width versus absorbed pump power for AO Q-switched Nd:CTGS laser (color online)

The variations of the pulse energy and the peak power with the pump power were shown in Fig. 5 and Fig. 6. Under the same pump power, going along with the raising of the repetition rate, the average output power increased and the pulse width broadened, while the pulse energy and peak power reduced. It could be seen that the shortest pulse width (38ns) was obtained at the repetition rate of 5 kHz under the pump power of 14.5W. Correspondingly, the maximum pulse energy was 110.6 μJ and the maximum peak power was 3.07 kW.

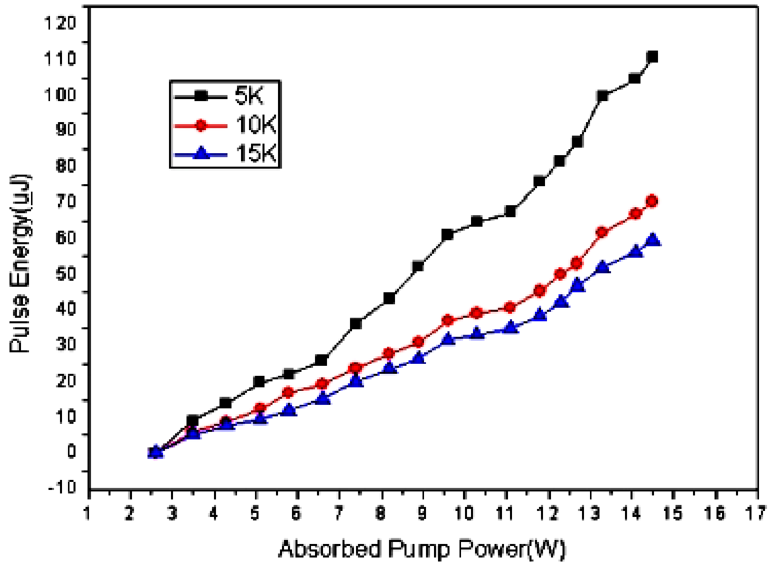

Fig. 5. The variation of pulse width versus absorbed pump power for AO Q-switched Nd:CTGS laser (color online)

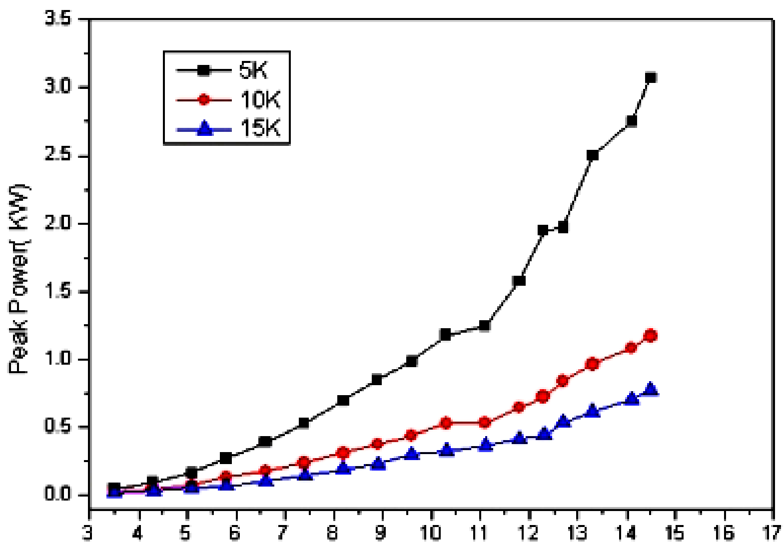

Fig. 6. The variation of pulse width versus absorbed pump power for AO Q-switched Nd:CTGS laser (color online)

Fig. 7 (a) showed the shortest pulse duration of 38 ns. The corresponding pulse train of the Q-switched operation was shown in Fig. 7 (b).

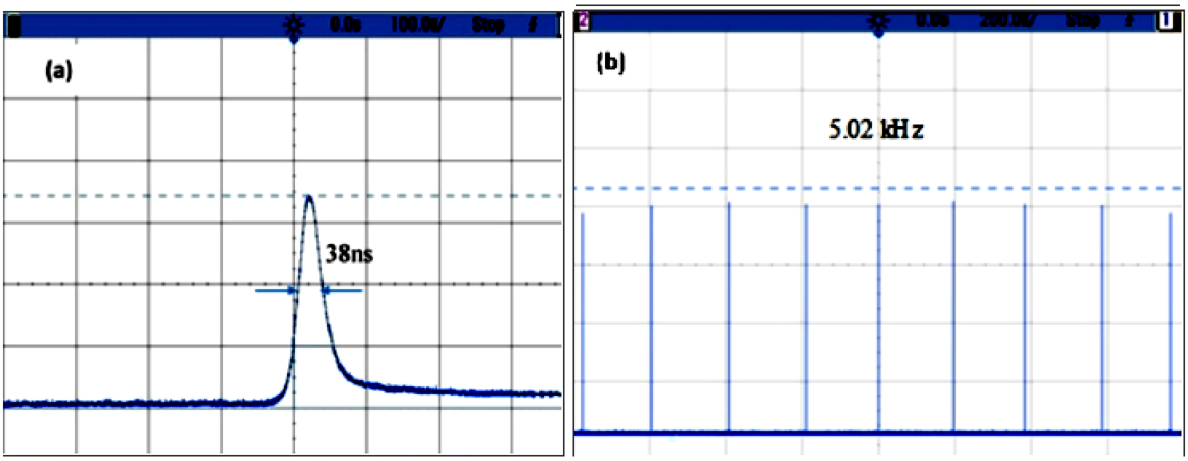

Fig. 7. The typical pulse profile of the active Q-switched Nd:CTGS laser at an absorbed pump power of 14.5Q: (a) Pulse duration; (b) Repetition frequency (color online)

4. Conclusions

The laser diode end-pumped acousto-optic Q-switched Nd:CTGS laser at about 1065 nm was demonstrated. A maximum average output power of 894 mW was obtained under the pump power of 14.5W at repetition rate of 15 kHz. The conversion efficiency of the output power from CW to Q-switching operation was amounted to 69%. The maximum peak power and the maximum pulse energy were calculated to be 3.07 kW and 110.6 μJ respectively at the repetition rate of 5 kHz under the pump power of 14.5 W, the corresponding minimum pulse width was 38ns.

Acknowledgements

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