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LD-pumped single-frequency passively Q-switched green laser

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Abstract

A LD-pumped single-frequency passively Q-switched Nd: YVO_4/KTP/Cr:YAG green laser is presented. Cr:YAG plays the double role of a passive Q-switch and a Brewster plate. With 900 mW incident pump laser, single-frequency passively Q-switched green laser with average power of 86 mW, pulse width of 14.7 ns, repetition rate of 140.8 kHz and peak power of 41.6 W is obtained. Measurement shows that the pulse amplitude and period between pulses are stable within ±1.5%.

Keywords: LD-pumped; Single frequency; Passive Q-switch; Green laser

1. Introduction

In recent years, saturable absorber passively Q-switched solid-state lasers are playing an important role in the development of laser techniques, especially in small or medium power lasers, because of their promising advantages such as design simplicity, low cost, reliability and structural compactness. Cr:YAG, which show a nonnegligible excited state absorption, have been favored due to their thermal and photochemical stability as well as high damage thresholds, both of which are necessary for long-life passive Q-switching [1]. Lamp and LD-pumped, Cr:YAG passively Q-switched Nd:YAG, Nd:YLF and Nd:YVO_4 infrared lasers were reported in many papers [2–4]. But few research papers on LD-pumped passively Q-switched green lasers with intracavity frequency doubling can be found in recent publication [5].

In this paper, a LD-pumped, Cr:YAG passively Q-switched Nd:YVO_4/KTP/Cr:YAG green laser is demonstrated. A simple tilt of Cr:YAG to a Brewster angle makes it play double roles of a passive Q-switch and a Brewster plate (BP). The Brewster plate and KTP crystal serve as a birefringent filter to realize the passively Q-switched green laser single-frequency operation. At last, we obtain a series of Q-switched green laser pulses with stable amplitude, duration and period.

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2. Theory analysis

It is well known that in passively Q-switched lasers, the pulse amplitude, duration and period between pulses usually exhibit jitters. Especially to intracavity frequency doubled lasers, "green problem" which is unavoidable in such intracavity second harmonic generation due to sum-frequency generation (SFG) would make the jitters harder [6]. The amplitude and repetition rate fluctuations have been a persistent problem, which has made the passive Q-switched green lasers inappropriate for many applications.

The fluctuations in passively Q-switched intracavity-doubled Nd:YVO_4 lasers also arises from coupling noise of various longitudinal modes by SFG in KTP crystal. A solution to reduce the noise is to force laser oscillation in the single longitudinal mode, as noted by Baer [7]. There are several methods for the noise reduction which have been developed by using intracavity elements, such as an etalon, a quarter-wave plate or a birefringent filter. A disadvantage of the former two methods is that the end-pumped laser output power is highly sensitive to such losses as may be introduced by the insertion of intracavity elements, while the latter method introduces less energy loss [8]. Here, a simple tilt of Cr:YAG to a Brewster angle would make it play double roles of a passive Q-switch and a Brewster

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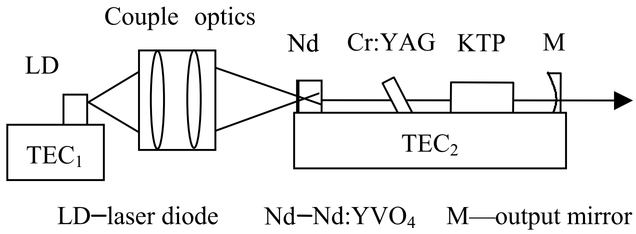

Fig. 1. Setup of single-frequency passively Q-switched green laser.

plate. Then, the Brewster plate (Cr:YAG) and the KTP crystal can serve as a birefringent filter to perform mode selection.

3. Experimental setup

Fig. 1 shows the experimental setup of a single-frequency passively Q-switched green laser. A QW-1000 laser diode made by Institute of Semiconductor, CAS, is used as pump source, $Nd:YVO_4$ and KTP grown by Shandong University used as laser crystal and frequency doubler, respectively, a piece of Cr:YAG grown by SIOM is used as passive Q-switch, a high-stability driver is used to offer current for LD and the temperature controller (TEC_1 and TEC_2).

LD is a continuous GaAlAs quantum-well laser diode with maximum power of 1.1 W, emission light cross-section of $100 \times 1\ \mu m^2$ and divergent angle of $7.8^\circ \times 28.6^\circ$. By TEC_1, its emitting wavelength is tuned to the $Nd:YVO_4$s absorption peak at 808.9 nm to make $Nd:YVO_4$ fully utilize the pump light.

Because the LD's emission angle is large and $Nd:YVO_4$ is thick, couple optics is used to reform the pump light. Measurement shows that the pump spot radius in $Nd:YVO_4$ is about 86 μm, which is smaller than that of the waist of TEM_{00} in $Nd:YVO_4$, so we can ensure only the TEM_{00} mode operation [9]. Experimental results show that the "dynamic aperture effect" of Cr:YAG also can restrain high-order modes from oscillating.

Left facet of $Nd:YVO_4$ (2.0 mm thick, 1.0 at% doped) is coated with 808 nm anti-reflection (AR) and 1064 nm high-reflection (HR) coatings as a reflective mirror of the resonator, and right facet with 1064 nm AR coatings. Both sides of Cr:YAG ($5 \times 5 \times 1.0\ mm^3$, $T_0 = 87\%$ for 1064 nm small signal) are polished and without anti-reflection coatings. Both sides of KTP ($2 \times 2 \times 9\ mm^3$, II-typed phase matching) coated with 1064/532 nm AR. Left-concave side of M ($\rho = 50$ mm) coated with 1064 nm HR and 532 nm AR, and right-plane side with 532 nm AR. In order to obtain narrow pulse width, all the components should be placed closely to reduce the resonator's length. Here, the resonator is about 17 mm long and is place on TEC_2 to keep structure and temperature stable.

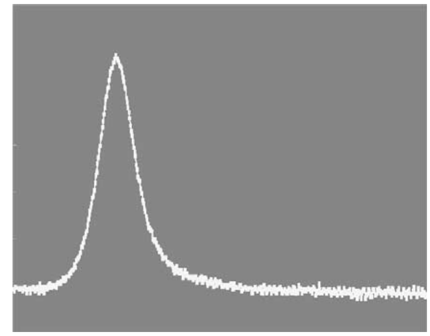

Fig. 2. Waveform of a green laser pulse.

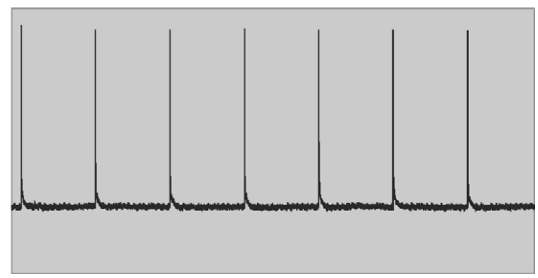

Fig. 3. Green laser pulse series.

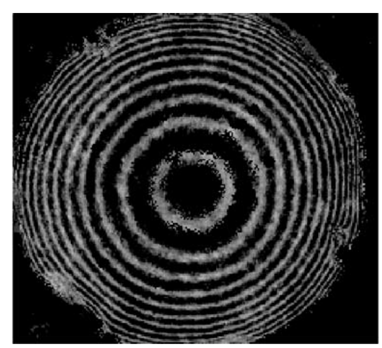

Fig. 4. Interference photography formed by green laser pulses passing through an etalon.

4. Results

The threshold of the laser is about 280 mW. When the incident pump power is 900 mW, the single-frequency passively Q-switched green laser with average power of 86 mW, pulse width of 14.7 ns, repetition rate of 140.8 kHz and peak power of 41.6 W is obtained.

Measurements show that the average power, peak power, repetition rate and single pulse energy all greatly increase, while pulse width decreases with pump power increasing. Fig. 2 is the waveform of a green laser pulse. Fig. 3 is the pulse series. Measurement shows that the pulse amplitude and period between pulses were stable within ±1.5%. Fig. 4 is the interference photography formed by the output green laser pulses passing through an etalon. It shows the laser is in single-frequency operation.

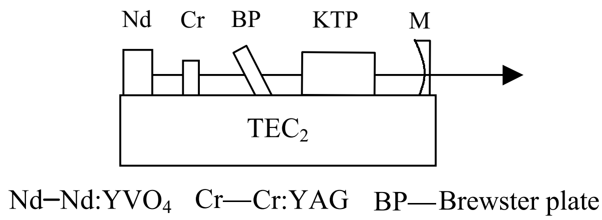

Fig. 5. Alternative resonator setup of Fig. 1.

5. Discussions

The Cr:YAG crystal has played double roles of a passive Q-switch and a Brewster plate in Fig. 1. In order to research two different roles on laser's performance, respectively, we construct an alternative resonator setup as shown in Fig. 5.

In Fig. 5, both sides of Cr:YAG are coated with anti-reflection coatings at 1064 nm wavelength. The Brewster plate is made by BK_7 polished glass. Experimental results of Fig. 5 are similar to Fig. 1. But Fig. 1 saves the need for antireflection coatings, more simple and compact.

If the Brewster plate is taken away, the setup of Fig. 5 would be a general passively Q-switched green laser. Measurement shows the pulse amplitude, duration and period between pulses exhibit jitters strongly, which shows the Brewster plate is very important for the laser's stable operation.

Just as mentioned above, in Fig. 5, if Cr:YAG is taken away instead, the setup would be a continuous wave (CW) green laser with a Brewster plate. But measurement shows that the laser is not yet in single-frequency operation at 900 mW incident pump power. We can find more than three modes oscillating. The results show that the Q-switch also has the role of mode selection when the pulse takes shape because different modes have different gains. Of course, at lower pump power, only the Brewster plate with KTP can ensure single-frequency CW operation.

6. Conclusions

By using a CW laser diode as pump source, Cr:YAG as a passive Q-switch and a Brewster plate, KTP as intracavity frequency doubler, we have realized single-frequency passively Q-switched operation of Nd:YVO_4 green laser. The all-solid-state Q-switched green laser has compact structure and can generate stable high-repetition-rate and high-peak-power green laser pulses.

Acknowledgements

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References

[1] Yuxin L, Lihuang L, Yangbin O, Xiaoke W. Absorption of excited state of Cr:YAG crystal. Acta Opt Sinca 2001;21:225–7.
[2] Shimony Y, Burshtein Z, Ben-Amar B. Repetitive Q-switching of a cw Nd:YAG laser using Cr:YAG saturable absorber. IEEE J Quantum Electron 1996;32:305–10.
[3] Bai Y, Wu N, Zhang J, Li J, Deng P. Passively Q-switched Nd:YVO_4 laser with a Cr:YAG crystal saturable absorber. Appl Opt 1997;36:2468–72.
[4] Shen HY, Wu RF, Zeng ZD. Laser diode pumping high-stability 1047 nm TEM_{00} mode cw Nd:YLF laser. Chin J Lasers 2000;B9:103–6.
[5] Zhao S, Zhang X, Wang Q. Diode-laser-pumped passively Q-switched Nd:S-FAP green laser. SPIE 2000;3929:261–5.
[6] Helmfrid S, Tatsuno K. Stable single-mode operation of intracavity-doubled diode-pumped Nd:YVO_4 lasers: theoretical study. J Opt Soc Am 1994;B11:436–45.
[7] Baer T. Large-amplitude fluctuations due to longitudinal mode coupling in diode-pumped intracavity-double Nd:YAG lasers. J Opt Soc Am 1989;B3:1175–80.
[8] Nagai H, et al. Low-noise operation of a diode-pumped intracavity-doubled Nd:YAG laser using a brewster plate. IEEE J Quantum Electron 1992;28:1164–8.
[9] Laporta P, Brussard M. Design criteria for mode size optimization in diode-pumped solid-state lasers. IEEE J Quantum Electron 1991;27:2319–26.