High peak power laser-diode-pumped passively Q-switched Nd:YVO_4/Cr^{4+}:YAG laser

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In this paper, we report a high peak power passively Q-switched laser-diode-end-pumped Nd:YVO_4/Cr^{4+}:YAG laser polarized along the C axis, generating 4.23-W average power and 18-kW peak power (144-μJ pulse power) with 8.0-ns time duration (29.4-kHz repetition rate) at 1064 nm while the pump power is 21.2 W.

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In recent years, laser-diode (LD) pumped all-solid-state passively Q-switched lasers have attracted much attention and developed quickly for their characteristics such as compact structure, little solidity, lower cost, easy application, and steadily running. Now minitype and low-power-pulse lasers have been widely applied to many domains such as micromachining, laser radar, laser ranging, and optical communication, so how to enhance the pulse energy of laser and the average power has been intensively studied. Nd:YAG and Nd:YVO_4 become the fittest crystals for gaining high peak power and high average power because of their good optical quality and lower price. Thus there are many studies about Nd:YAG crystal[1−3]. However, Nd:YVO_4 crystal has many virtues such as big absorption coefficient, wide absorption band width (Nd:YAG ~4 ns, Nd:YVO_4 ~21 ns), big emission section (Nd:YAG $\sim 2.4 \times 10^{-19}$, Nd:YVO_4 $\sim 25 \times 10^{-19}$), and linearly polarized output. So Nd:YVO_4 crystal could contain the drift of output wavelength induced by temperature changing or LD aging, and could prolong the using time. Under the same conditions, Nd:YVO_4 has lower threshold value and higher slope efficiency than Nd:YAG, so Nd:YVO_4 is more suitable for continuous wave (CW) and Q-switched pulse running[4−6]. In addition, many laser crystals could be new type compellent crystals in Q-switched laser, and Nd:YVO_4 crystal is the most prospective one. Now LD-pumped minitype and low power Cr^{4+}:YAG Q-switched laser is studied much more, but literature analyzing high peak power laser is very little yet.

In this paper, the output characteristics of Cr^{4+}:YAG passively Q-switched LD-end-pumped laser are analyzed, obtaining high average power and high peak power Q-switching output, generating 4.23-W average power and 18-kW peak power (144-μJ pulse power) with 8.0-ns time duration (29.4-kHz repetition rate) at 1064 nm while the pump power is 21.2 W.

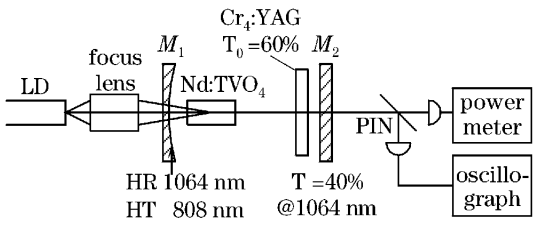

Fig. 1. The schematic setup of the LD-pumped passively Q-switched Nd:YVO_4/Cr^{4+}:YAG laser.

The experimental setup with a plano-concave cavity is shown in Fig. 1. FAP-System^{TM} optical fiber coupling output diode laser (Coherent Co., USA) was used. The center wavelength was 808 nm, the maximum output power was 30 W, the output aperture of the fiber was 0.8 mm, the numerical aperture was 0.22. The pump power was injected into the crystal with the dimension of 3×3×10 mm^3 via a focusing coupler system with a focusing ratio of 1:0.8. The crystal was cut along C axis and doped with 0.5 at.-% Nd^{3+}. The injection efficiency was about 85%. The front surface of crystal was vertical to the optical axis and coated with antireflection (AR) film of 808 and 1064 nm, the back surface of crystal was coated with AR film of 1064 nm. In order to prevent forming resonance between the back surface and the front surface, the back surface had an angle of about 1° with the front surface. The crystal was set in a copper cooler cooled with circulating water. The resonator consisted of two mirrors. A concave mirror with curvature radius of 200 mm was used as input coupler and a plane mirror with 40% transmission at 1064 nm was used as output coupler. The outer surface of the concave mirror was coated with AR film of 808 nm, the inner surface was coated with high reflection (HR) film of 1064 nm and AR film of 808 nm also. The initial transmission of Cr^{4+}:YAG crystal was 60%, the dimension of it was 4×4×2 mm^3. The Cr^{4+}:YAG crystal was set in the copper cooler nearly by the output mirror. Because of the high-power pumping, the thermal lens effect of the laser crystal must be taken into account, which could influent the stability of the resonator, so the length of the resonator was selected as 60 mm. In this experiment, LP-3B laser power meter was used to detect the output average power of the laser, PIN silicon fast photodiode was used to accept the signal, TDS620A digital oscilloscope was used to observe the time domain characteristic of the pulse.

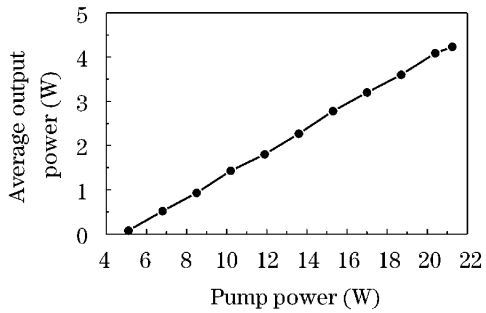

Fig. 2. Average output power versus input power.

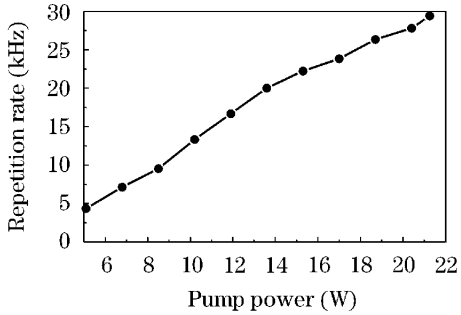

Fig. 3. Pulse repetition rate versus input power.

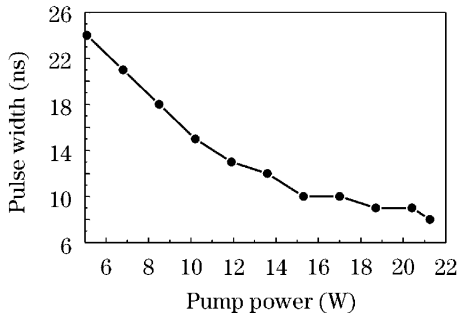

Fig. 4. Pulse width versus input power.

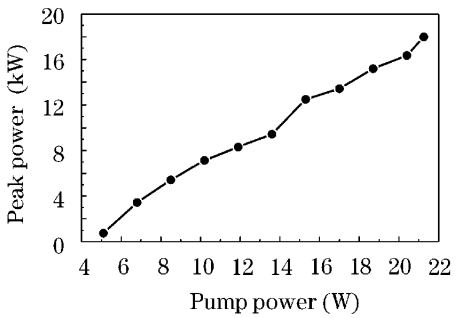

Fig. 5. Pulse peak power versus input power.

In this experiment, the initial transmission of Cr^{4+}:YAG was 60%. Changing the output coupler mirror, the best output couple transmitivity of 45% was found for gaining high peak power. The output power

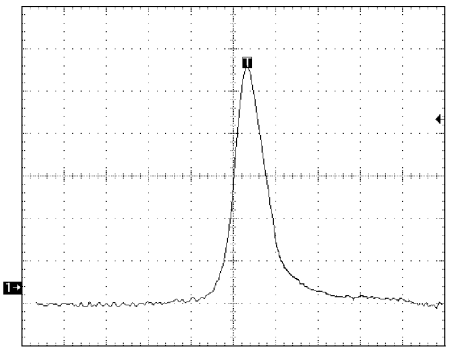

Fig. 6. The pulse width with the pump power of 21.2 W.

arrived 4.23 W, and the peak power arrived 18 kW simultaneously. The results of average power, pulse width, pulse repetition rate, peak power, and the wave form of Q-switched pulse were shown in Figs. 2–6.

As shown in the experimental results, with the increase of the pump power, both the output average power and the repetition rate increased linearly. Simultaneously the width of pulse was minished with the increase of the pump power. So the peak power increased linearly with the increase of the pump power, generating 4.23-W average power and 18-kW peak power (144-μJ pulse power) with 8.0-ns time duration (29.4-kHz repetition rate) at 1064 nm while the pump power increased to 21.2 W. Compared with the results of Ref. [8], the output average power of this experiment (4.23 W) was higher than their result (3.8 W). However the peak power of this paper was lower because of the wider pulse width (8 ns, 6 ns was reported in other papers). The reason was that the dimension of the elements used in this experiment was too big to shorten the length of the resonator.

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References

1. Y. X. Bai, N. L. Wu, J. Zhang, J. Q. Li, S. Q. Li, J. Xu, and P. Z. Deng, Appl. Opt. **36,** 2468 (1997).
2. U. Keller, *Nonlinear Optics in Semiconductors II, Semiconductors and Semimetals* (Academic Press, New York, 1999) pp. 211–285.
3. L. Fulop, L. Fulbert, and E. Molva, in *Proceedings of Conference on Lasers and Electro-Optics 1998* 136 (1998).
4. J. Song, C. Li, N. S. Kim, and K. Ueda, Appl. Opt. **39,** 4954 (2000).
5. Y. F. Chen, S. W. Tsai, and S. C. Wang, Opt. Lett. **25,** 1442 (2000).
6. Y. F. Chen and Y. P. Lan, Appl. Phys. B **74,** 415 (2002).
7. C. Li, J. Song, D. Shen, N. S. Kim, J. Lu, and K. Ueda, Appl. Phys. B **70,** 471 (2000).
8. A. Agnesi and S. Dell'acqua, Appl. Phys. B **76,** 351 (2003).