IOPscience iopscience.iop.org

Home Search Collections Journals About Contact us My IOPscience

Diode-Pumped Passive Q-Switched 946-nm Nd:YAG Laser with 2.1-W Average Output Power

This content has been downloaded from IOPscience. Please scroll down to see the full text.

2005 Chinese Phys. Lett. 22 1420

(http://iopscience.iop.org/0256-307X/22/6/033)

View the table of contents for this issue, or go to the journal homepage for more

Download details:

IP Address: 159.226.35.202
This content was downloaded on 28/09/2016 at 10:07

Please note that terms and conditions apply.

You may also be interested in:

Diode-Pumped Passive Q-Switched 946 nm Nd:YAG Laser with aGaAs Saturable Absorber
Wang Su-Mei, Zhang Qiu-Lin, Zhang Ling et al.

Diode-pumped Q-switched 946 nm Nd:YAG ceramic laser
C Zhang, X Y Zhang, Q P Wang et al.

High Power Diode-End-Pumped Nd:YAG 946-nm Laser and ItsEfficient Frequency Doubling
Zhou Rui, Zhao Shi-Yong, Cai Zhi-Qiang et al.

Diode-Pumped Compact cw Frequency-Doubled Nd:YAG Laser in theWatt Range at 473 nm
Li Ping-Xue, Li De-Hua, Zhang
Zhi-Guo et al.

Highly efficient continuous-wave Nd:YAG ceramic lasers at 946 nm
H Y Zhu, C W Xu, J Zhang et al.

Experimental investigation of a diode-pumped powerful continuous-wave dual-wavelength Nd:YAG laser at 946 and 938.6 nm
F Chen, X Yu, R P Yan et al.

Compact High-Power Blue Light from a Diode-PumpedIntracavity-Doubled Nd:YAG Laser
Li De-Hua, Li Ping-Xue, Zhang
Zhi-Guo et al.

Diode-Pumped Passive Q-Switched 946-nm Nd:YAG Laser with 2.1-W Average Output Power *

ZHANG Ling(张玲)**, LI Chun-Yong(李春勇), FENG Bao-Hua(冯宝华), WEI Zhi-Yi(魏志义), LI De-Hua(李德华), FU Pan-Ming(傅盘铭), ZHANG Zhi-Guo(张治国)

Laboratory of Optical Physics, Institute of Physics, Chinese Academy of Sciences, PO Box 603, Beijing 100080

(Received 2 February 2005)

We demonstrate a diode-pumped passive Q-switched 946 nm Nd:YAG laser with a diffusion-bonded composite laser rod and a co-doped Nd,Cr:YAG as saturable absorber. The average output power of 2.1 W is generated at an incident pump power of 14.3 W. The peak power of the Q-switched pulse is 643 W with 80 kHz repetition rate and 40.8 ns pulse width. The slope efficiency and optical conversion efficiency are 17.6% and 14.7%, respectively.

PACS: 42. 55. Xi, 42. 60. Gd, 42. 55. Rz

Diode-pumped passive Q-switched lasers have been widely used in laser communication, remote sensing and nonlinear optics. Cr^{4+}:YAG crystal is a perfect saturable absorber owing to its excellent optical, thermal and mechanical properties. Co-doped Nd,Cr:YAG crystal is another widely used saturable absorber. Many studies about passive Q-switched 1064-nm lasers have been reported.[1−4] Passive Q-switched 946-nm lasers have attracted great attention because of their potential to generate high-power and high-repetition-rate blue lasers through frequency doubling.[5−8] However, it is more difficult to realize the passive Q-switched 946 nm lasers owing to the reabsorption loss of the quasi-three level system and the small stimulated emission cross-section compared with that of the 1064 nm lasers. In order to obtain sufficient intracavity intensity to realize the 946-nm Q-switched operation, high pump power must be cast to the laser crystal. As a result, the laser crystal will be loaded with enormous heat. Accordingly, the reabsorption loss becomes more serious. In order to minimize the heat effect effectively, we employ a diffusion-bonded composite laser rod instead of the conventional crystal. The composite laser rod is reliable for heat transfer from both the facets of the Nd:YAG crystal through two undoped YAG caps when the Nd:YAG crystal is operating at high pump power. In our experiment, we select a co-doped Nd,Cr:YAG as saturable absorber because this crystal has lower saturation intensity according to Refs. [9,10]. We demonstrate experimentally high-average-output-power Q-switched operation (to 2.1 W) of 946 nm transition with a compact linear cavity. This is, to the best of our knowledge, the highest average output power for passive Q-switched 946-nm laser. At an incident pump power of 14.3 W, 80-kHz repetition rate and 40.8-ns pulse width of the Q-switched pulse have also been achieved.

The experimental setup is shown in Fig. 1. We use a simple and compact linear cavity in length of 4 cm. The pump source is a 200-μm fibre-coupled diode laser with a numerical aperture of 0.22. The 808-nm pump light from a fibre is coupled into a diffusion-bonded Nd:YAG (3-mm YAG, 3-mm 1.0 at.% Nd:YAG, and 3-mm YAG). The pump facet of the laser rod is coated for high transmission (HT) at 808 nm, high reflection (HR) at 946 nm, while HT at 1064 nm and 1320 nm is specified to suppress parasitic oscillation at these transitions. The other side of the rod is coated with antireflection (AR) at 946 nm, 1064 nm and 1320 nm. The saturable absorber is a 1 mm-long co-doped Nd,Cr:YAG crystal with an initial transmission of 91%. In order to reduce the loss of the laser cavity, both the sides of the crystal were AR coated for 946 nm. The laser rod and the saturable absorber were both cooled directly with flowing water ($T = 14.6°$C). The output coupler was a concave mirror which had 5% transmission at 946 nm with a curvature radius of 50 mm.

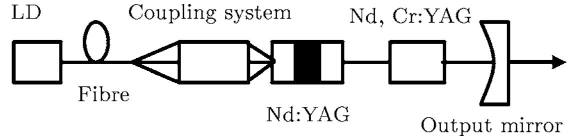

Fig. 1. Schematic of the passive Q-switched 946 nm Nd:YAG laser.

From analysis of the coupled rate equation, the criterion for good passive Q-switching is given by[11]

$$\frac{\ln(1/T_0^2)}{\ln(1/T_0^2)+\ln(1/R)+L}\frac{\sigma_{gs}}{\sigma}\frac{A}{A_s} \gg \frac{\gamma}{1-\beta}, \quad (1)$$

where T_0 is the initial transmission of the saturable absorber, R is the reflectivity of the output mirror, L

* Supported by the National Natural Science Foundation of China under Grant Nos 60278024 and 60225005.
** Email: zhangling@aphy.iphy.ac.cn
©2005 Chinese Physical Society and IOP Publishing Ltd

is the nonsaturable intracavity round-trip dissipative optical loss, σ_{gs} is the ground-state absorption cross section of the saturable absorber, σ is the stimulated-emission cross section of the gain medium, A/A_s is the ratio of the effective area in the gain medium and in the saturable absorber, γ is the inversion reduction factor (γ=1 and γ=2 correspond to four-level and three-level systems), and β is the ratio of the excited-state absorption cross section to that of the ground-state absorption in the saturable absorber. The basic parameters used in our experiment are $T_0 = 91\%$, $R = 95\%$, $L = 0.05$, $\sigma_{gs} = 4 \times 10^{-18}\,\mathrm{cm}^2$, $\sigma = 4 \times 10^{-20}\,\mathrm{cm}^2$, $A/A_s = 0.97$, $\gamma = 2$, $\beta = 0.275$. According to the parameters, the left and right sides of the equation are calculated to be 63.1 and 2.76, respectively, which meets the criterion for good passive Q-switching. The threshold of the Q-switched pulse is 2.39 W owing to the efficient mode match between the pump light and the oscillating light. Figure 2 presents the average output power as a function of the incident pump power. At 14.3-W incident pump power, the maximum average output power is 2.1 W with a slope efficiency of 17.6% and an optical conversion efficiency of 14.7%. The far-field beam spatial profile of the Q-switched 946 nm laser at the average output power of 1.5 W is measured using a small pinhole scanning across the laser beam. The result is shown in Fig. 3. A nearly Gaussian beam intensity profile is obtained. The Q-switched pulse temporal behaviour was recorded by a digital oscilloscope (Tektronix 500 MHz bandwidth and 500 MS/s) and a fast photodiode with a rising time of less than 1 ns. Figure 4 shows a typical Q-switched laser pulse with duration of 46 ns, which was obtained at the incident pump power of 8 W. Figure 5 presents an oscilloscope trace of 946 nm Q-switched pulses at the incident pump power of 4.6 W. The Q-switched pulses train is very stable with a pulse amplitude and repetition rate jitter of less than 1%. The pulse amplitude and repetition rate jitter increase with the incident pump power. The repetition rate and pulse width of the Q-switched pulse as a function of the incident pump power are shown in Fig. 6. It is obvious that the repetition rate of the Q-switched pulse increases almost linearly with the incident pump power, whereas the pulse width decreases with the incident pump power. With an incident pump power of 14.3 W, the Q-switched pulse repetition rate is 80 kHz with pulse width of 40.8 ns. The peak power of 643 W and the pulse energy of 26.3 μJ were also obtained. With the further increase of the incident pump power, we observed the similar phenomena reported in Ref. [7], the output of the pulse repetition rate consists of a repetitive pulse set, in which a large pulse is followed by one or more smaller pulses.

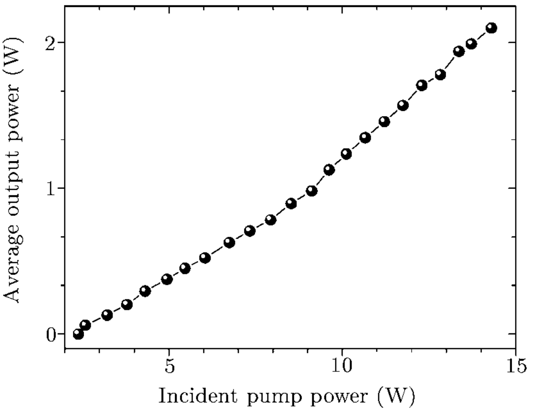

Fig. 2. The average output power as a function of the incident pump power.

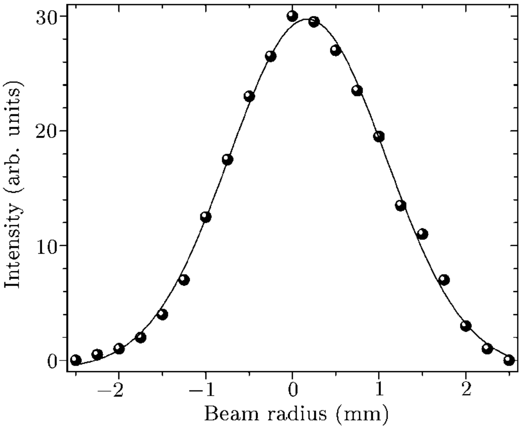

Fig. 3. The far-field beam spatial profile of the Q-switched 946 nm laser at the average output power of 1.5 W.

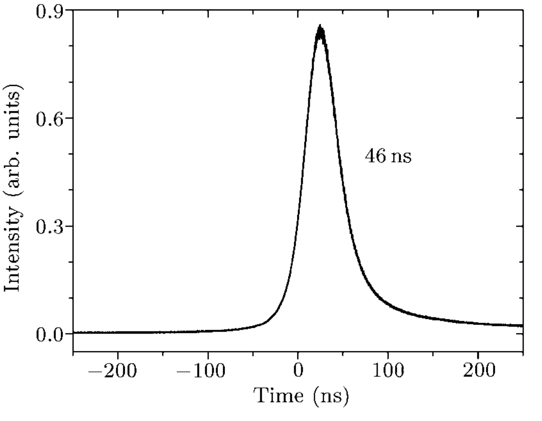

Fig. 4. Pulse shape of the passive Q-switched 946 nm laser emission.

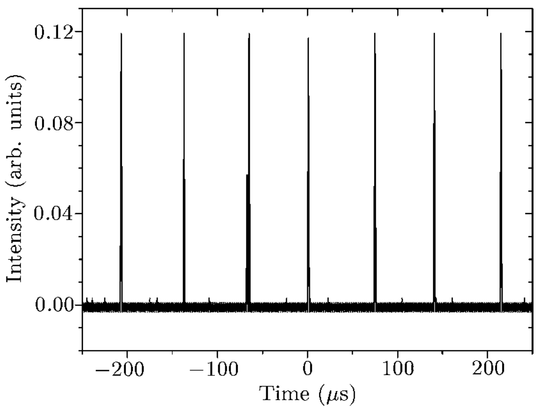

Fig. 5. An oscilloscope trace of 946 nm Q-switched pulses.

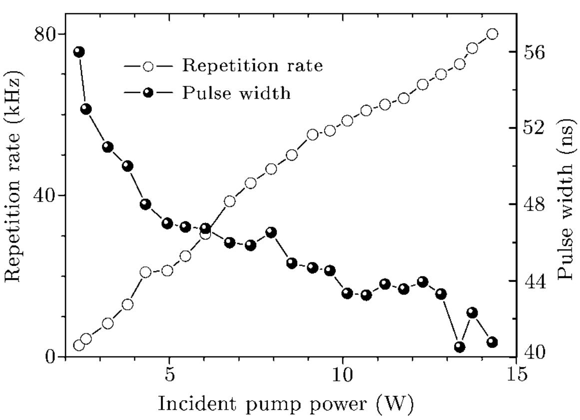

Fig. 6. The repetition rate and pulse width of the Q-switched pulse as a function of the incident pump power.

In conclusion, we have demonstrated a diode-pumped passive Q-switched 946 nm Nd:YAG laser with a composite laser rod and a saturable absorber of Nd,Cr:YAG crystal. At an incident pump power of 14.3 W, the average output power of 2.1 W with a slope efficiency of 17.6% is obtained. The result is the highest average output power for passive Q-switched 946 nm laser reported before. The pulse repetition rate of 80 kHz with pulse width of 40.8 ns and the Q-switched pulse energy of 26.3 μJ are also achieved at the same incident pump power.

References

[1] Dong J, Deng P Z, Lu Y T, Zhang Y H, Liu Y P, Xu J and Chen W 2000 *Opt. Lett.* **25** 1101

[2] Ng S P, Tang D Y, Qin L J and Meng X L 2004 *Opt. Commun.* **229** 331

[3] Pan L, Hou X Y, Li Y F and Sun Y M 2004 *Opt. Laser Technol.* **36** 121

[4] Li C Y, Li P X, Li D H, Feng B H, Fu P M, Zhang Z G and Zhang S W 2004 *Chin. Phys. Lett.* **21** 313

[5] Hong J H, Sinclair B D, Sibbett W and Dunn M H 1992 *Appl. Opt.* **31** 1318

[6] Lv L B, Wang L, Fu P M, Chen X B, Zhang Z G, Gaebler V, Li D H, Liu B N, Eichler H J, Zhang S W, Liu A H and Zhu Z 2001 *Opt. Lett.* **26** 72

[7] Kellner T, Heine F, Huber G and Kuck S 1998 *Appl. Opt.* **37** 7076

[8] Li D H, Wang L, Gao C Q, Zhang Z G, Feng B H, Gaebler V, Liu B N, Eichler H J, Zhang S W, Liu A H and Shen D Z 2002 *Chin. Phys. Lett.* **19** 504

[9] Yang L, Feng B, Zhang Z, Gaebler V, Liu B and Eichler H J 2003 *Opt. Mater.* **22** 59

[10] Yang L, Feng B H, Zhang Z G, Gaebler V, Liu B N and Eichler H J 2003 *Chin. Phys.* **12** 886

[11] Xiao G H and Bass M 1997 *IEEE J. Quantum Electron.* **33** 41