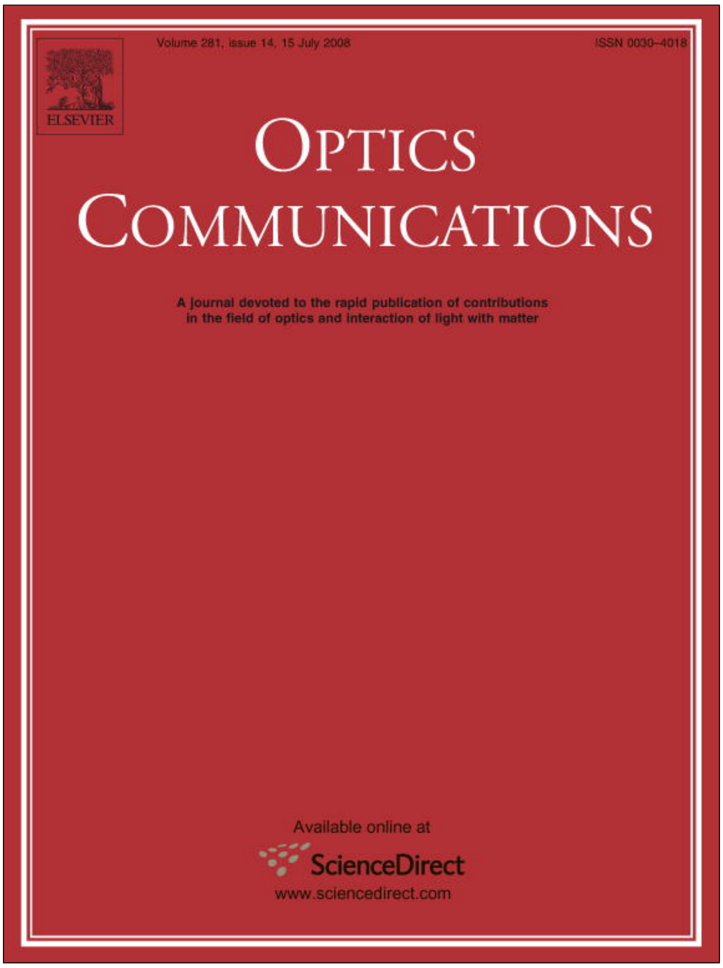
Volume 281, issue 14, 15 July 2008
ISSN 0030-4018
ELSEVIER
OPTICS COMMUNICATIONS
A journal devoted to the rapid publication of contributions in the field of optics and interaction of light with matter
Available online at
ScienceDirect
www.sciencedirect.com

Available online at www.sciencedirect.com

ScienceDirect

Optics Communications 281 (2008) 3853–3855

OPTICS COMMUNICATIONS

www.elsevier.com/locate/optcom

Diode-pumped intra-cavity doubled Nd:$LuVO_4$ laser at 458 nm

Kunna He [a,b,*], Chunqing Gao [a], Zhiyi Wei [b], Dehua Li [b], Zhiguo Zhang [b], HuaiJin Zhang [c], Jiyang Wang [c]

[a] *Department of Opto-Electronics, Beijing Institute of Technology, Beijing 100081, China*
[b] *Laboratory of Optical Physics, Institute of Physics, Chinese Academy of Sciences, P.O. Box 603, Beijing 100190, China*
[c] *National Laboratory of Crystal Materials and Institute of Crystal Materials, Shandong University, Jinan 250100, China*

Received 18 February 2008; accepted 30 March 2008

Abstract

We have demonstrated a diode-pumped intra-cavity frequency doubling Nd:$LuVO_4$ laser operating at 916 nm with a Z-folded cavity. A 10-mm long LBO crystal, cut for critical type I phase matching at 912 nm, is used for the experiment. A maximum output power of 330 mW at 458 nm has been achieved at pump power of 22 W. The optical-to-optical conversion efficiency and slope efficiency is 1.5% and 2.3%, respectively. The power instability at the maximum output power in 30 min is better than 3%.

PACS: 42.55.Xi; 42.65.Ky

Keywords: Diode-pumped lasers; Harmonic generation

1. Introduction

Deep blue lasers with wavelength below 460 nm have attracted much attention for their short wavelength and large photon energy which ensured extensive applications in many fields such as color display technologies, underwater communication, high-density optical storage, etc. Since Fan and Byer [1] first introduced diode-pumped quasi-three-level laser in 1987, intra-cavity frequency doubling Nd^{3+} lasers near 900 nm has been recognized as an effective way to realize deep blue laser. Up to now, deep blue lasers mainly used Nd:YVO_4 and Nd:$GdVO_4$ crystals from the vanadate family as the laser gain media in view of their superior optical properties [2–7]. Yet recently a new laser host of Nd:$LuVO_4$ from that family aroused many people's interest because that it has larger absorption and emission cross sections than those of Nd:YVO_4 and Nd:$GdVO_4$ [8]. However, there are not many reports relevant to Nd:$LuVO_4$ blue laser so far as the $^4F_{3/2} \rightarrow {}^4I_{9/2}$ transition at 916 nm is difficult to obtain due to many difficulties such as serious re-absorption loss and very small stimulated emission cross section compared with the $^4F_{3/2} \rightarrow {}^4I_{11/2}$ transition at 1066 nm [9,10]. In 2006, our group realized the 916 nm and 458 nm Nd:$LuVO_4$ laser with linear resonator for the first time [11], but the output power, slope efficiency and optical conversion efficiency of blue laser were rather low. The output power was only about 50 mW, slope efficiency and optical-to-optical conversion efficiency was 0.4% and 0.7%, respectively. Based on previous works, we present a frequency doubling Nd:$LuVO_4$ laser with a Z-folded cavity in this paper, output power of 330 mW at 458 nm is obtained under a pump power of 22 W, the optical-to-optical conversion efficiency and slope efficiency is 1.5% and 2.3%, respectively. The power instability at the maximum output power is better than 3% within 30 min.

* Corresponding author. Address: Department of Opto-Electronics, Beijing Institute of Technology, Beijing 100081, China. Tel./fax: +86 10 82649074.
E-mail address: hekunna@aphy.iphy.ac.cn (K. He).

0030-4018/$ - see front matter © 2008 Elsevier B.V. All rights reserved.
doi:10.1016/j.optcom.2008.03.063

2. Experimental setup

The experiment layout is shown in Fig. 1. The pump source was a high-brightness fiber-coupled diode laser with a fiber core diameter of 200 μm and numerical aperture of 0.22. A 1:1 coupling system was used to inject the pump laser into the $Nd:LuVO_4$ crystal which was cut at the dimensions of $3 \times 3 \times 5.5\ mm^3$ and doped with 0.1 at.% Nd^{3+} concentration. To keep a stable and efficient output, we mounted the $Nd:LuVO_4$ crystal in a water-cooled heat sink. To decrease the loss caused by inserting another cavity mirror and prevent parasitic oscillations in the $Nd:LuVO_4$ crystal, we coated one crystal facet for HR at 916 nm and HT at 808 nm, 1066 nm and 1342 nm, and coated the other side for AR at all these wavelengths. A LBO crystal was used for second harmonic generation. Though LBO has a relatively low nonlinear coefficient d_{eff}(pm/V), its walk-off angle is so small that it is possible to obtain a high doubling efficiency by using a longer crystal. The LBO crystal had a length of 10 mm and a cross section of $3 \times 3\ mm^2$. It was AR coated for 912 nm and 456 nm on both sides, and was cut for critical type I phase matching ($\theta = 90°$, $\varphi = 21.9°$) at 912 nm. The temperature of the LBO was set at 21.2 °C in order to achieve the phase matching at 916 nm. Moreover, to yield high doubling efficiency, the LBO crystal was placed in the focus point of the laser mode between M2 and M3. The radii curvature of the M1, M2 and M3 mirror are 100 mm, 80 mm and 80 mm, respectively. The M1 and the M3 were both coated for HR at 916 nm and 458 nm. The M2 was coated for HR at 916 nm and HT at 458 nm.

Resonator analysis with ABCD matrix shows that our Z-folded cavity is not sensitive to the thermal effect. Simulating the focal length of thermal lens from 40 mm to 300 mm, the ratio of spot radius of pump laser and oscillating laser is nearly constant, which indicates that both laser beams can match up each other very well and the oscillating laser can stably operate under high pump power. Moreover, the spot radius in the LBO crystal is relatively small. When the thermal lens focal length changes from 40 mm to 300 mm, the spot radius in the LBO crystal will alter just in a narrow bound (between 39 μm and 53 μm), which is benefit the doubling efficiency.

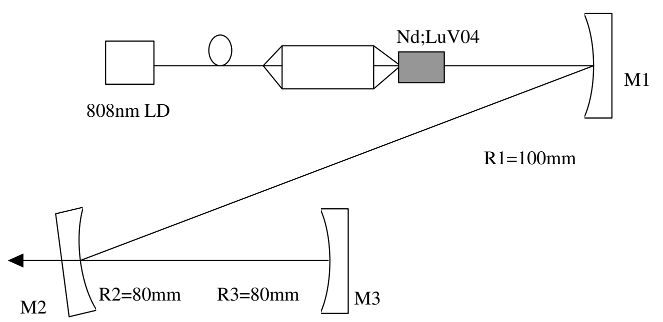

Fig. 1. Setup of the intra-cavity frequency doubled $Nd:LuVO_4$ laser.

3. Experimental results

Firstly, we tested the characteristics of the fundamental light with a simple linear resonator. The radius curvature of the output mirror was 100 mm and the transmission at 916 nm was 3.6%. From Fig. 2, we can see that the output power of the 916 nm was not sensitive to the temperature. Under different temperatures (15 °C, 10 °C and 6 °C), the output power was 2.30 W, 2.40 W and 2.52 W, respectively.

Next, we carried out the intra-cavity frequency doubling experiment. From the output spectrum of the blue laser in Fig. 3 we can see the emission was clearly presented at 458 nm. The output power of the blue laser versus the incident pump power is shown in Fig. 4. The laser threshold was 7.6 W. The maximum output power was 330 mW at the pump power of 22 W, and it is obviously higher than that one of the linear resonator demonstrated by Zhang et al. [11]. The reason may be that good mode match and small spot radius in the nonlinear crystal usually cannot be obtained at the same time in the linear cavity. However, our Z-folded cavity can ensure not only good match between the incident pump laser and the oscillating laser,

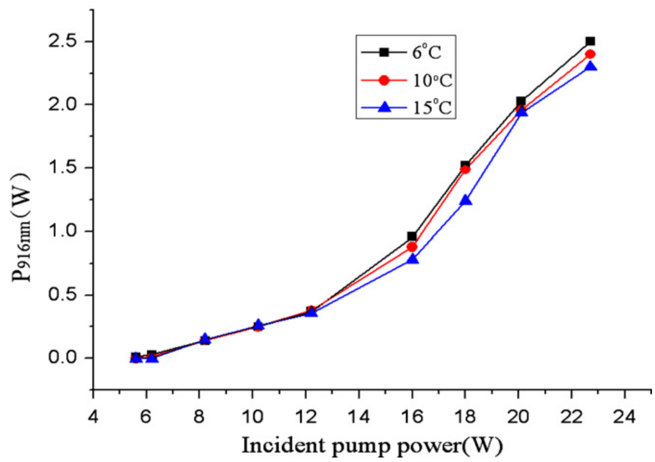

Fig. 2. Output power at 916 nm for $T = 3.6\%$ versus pump power.

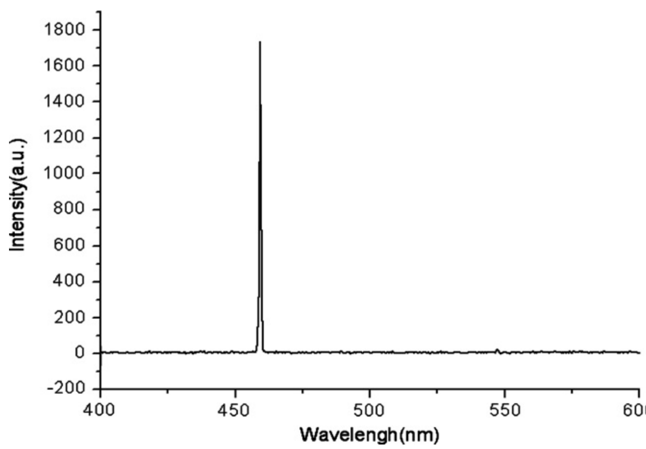

Fig. 3. Optical spectrum of intra-cavity frequency doubling $Nd:LuVO_4$ laser.

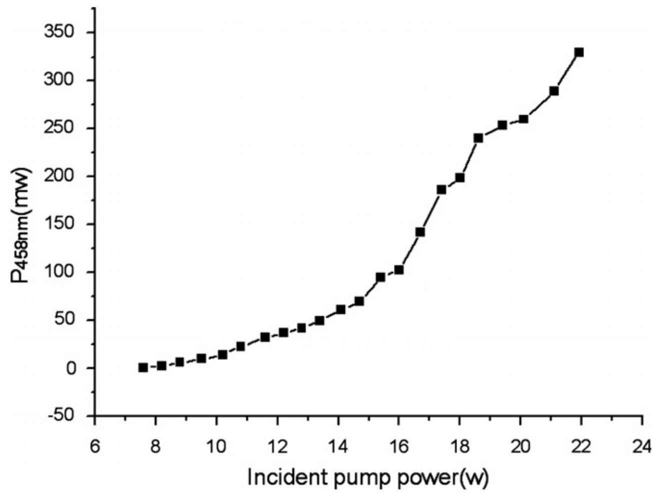

Fig. 4. Output power at 458 nm versus pump power.

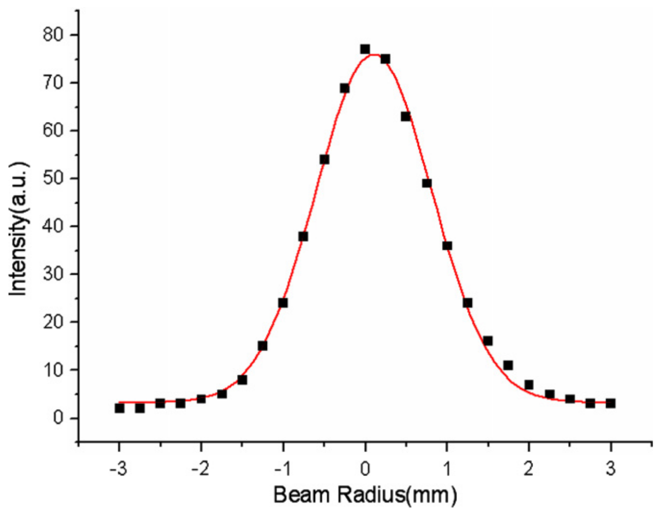

Fig. 5. The far-field beam spatial profile of the blue laser.

but also smaller spot radius in the LBO crystal. Moreover, the oscillating laser can pass through the LBO two times which benefits for the efficiency of intra-cavity frequency doubling experiment. That is why we generate higher output power with the Z-type cavity.

In our experiment, the far-field beam spatial profile of the blue laser at output power of 300 mW was measured by using a small pinhole scanning across the laser beam. The data and the Gaussian curve fitted result were shown in Fig. 5, from which we can see that the laser was oscillated in the quasi-fundamental transverse mode. We also observed the stability of the system by monitoring the blue laser output power. The instability of the output blue laser at the maximum output power was less than 3% (rms) within 30 min.

4. Conclusion

In conclusion, we have achieved 458 nm blue laser by intra-cavity frequency doubling $Nd:LuVO_4$ laser at 916 nm with critical type I LBO phase match, output power of 330 mW was obtained under pump laser of 22 W. The optical-to-optical conversion efficiency and slope efficiency was 1.5% and 2.3%, respectively. The power instability at the maximum output power in 30 min was better than 3%.

Acknowledgements

We gratefully acknowledge the financial support by the National Natural Science Foundation of China (60490281, 60621063, 50572054, 50590401) and the Grand for State Key Program of China (Nos. 2007CB815104, 2004CB619002).

References

[1] T.Y. Fan, R. Byer, Opt. Lett. 12 (1987) 809.
[2] F. Jia, Q. Xue, Q. Zheng, Y. Bu, L. Qian, Appl. Phys. B 83 (2006) 245.
[3] Y.D. Zavartsev, A.I. Zagumennyi, F. Zerrouk, S.A. Kutovoi, V.A. Mikhailov, V.V. Podreshetnikov, A.A. Sirotkin, I.A. Shcherbakov, J. Quantum Electron. 33 (2003) 651.
[4] C. Czeranowsky, M. Schmidt, E. Heumann, G. Huber, S. Kutovoi, Y. Zavartsev, Opt. Commun. 205 (2002) 361.
[5] V. Ruseva, J. Hald, Appl. Opt. 42 (2006) 5500.
[6] Q.H. Xue, Y.K. Bu, F.Q. Jia, Q. Zheng, Opt. Commun. 258 (2006) 67.
[7] Q.H. Xue, Q. Zheng, Y.K. Bu, F.Q. Jia, L.S. Qian, Opt. Lett. 31 (2006) 1070.
[8] C. Maunier, J.L. Doualan, R. Moncorgé, A. Speghini, M. Bettinelli, E. Cavalli, J. Opt. Soc. Am. B 19 (2002) 1794.
[9] Chunyu Zhang, Ling Zhang, Zhiyi Wei, Chi Zhang, Yongbing Long, Zhiguo Zhang, HuaiJin Zhang, Jiyang Wang, Opt. Lett. 31 (2006) 1435.
[10] Chun-Yu Zhang, Chun-Qing Gao, Zhi-Feng Lin, Ming-Wei Gao, Ling Zhang, Zhi-Yi Wei, Chi Zhang, Zhi-Guo Zhang, HuaiJin Zhang, Ji-Yang Wang, Chinese Phys. Lett. 23 (2006) 2763.
[11] Ling Zhang, Chun-Yu Zhang, Zhi-Yi Wei, Zhang Chi, Yong-Bing Long, Zhi-Guo Zhang, HuaiJin Zhang, Ji-Yang Wang, Chinese Phys. Lett. 23 (2006) 1192.