1047-nm all-solid-state laser based on Nd:LuLF

Rui Li (李 锐), Ting Yu (余 婷), Lianhan Zhang (张连翰), Weibiao Chen (陈卫标)*, and Yin Hang (杭 寅)**

Research Center of Space Laser Information Technology, Key Laboratory of Materials for High Power Laser, Shanghai Institute of Optics and Fine Mechanics, Chinese Academy of Sciences Shanghai 201800, China

**Corresponding author: wbchen@mail.shcnc.ac.cn;* ***corresponding author: yhang@siom.ac.cn*

Received October 8, 2010; accepted November 2, 2010; posted online January 28, 2011

A compact all-solid-state continuous-wave (CW) laser at 1047 nm is developed based on Nd:LuLF, which is grown through the Czochralski technique. From the laser system, 1.3-W laser can be obtained, which corresponds to the slope efficiencies of 20.1% and 49.5% with respect to the incident and absorbed pump powers, respectively. To the best of our knowledge, this is the highest power level achieved at 1047 nm based on the Nd:LuLF crystal.

OCIS codes: 140.3390, 140.3590, 160.3900.
doi: 10.3788/COL201109.021404.

1047-nm laser can be used as a fundamental wave to produce 523.5-nm green laser emission, which has significant applications in display technology and underwater communication. A 1047-nm laser can now be obtained based on Nd:YLF or Nd:LuLF crystal on the transition of $^4F_{3/2} \rightarrow ^4I_{11/2}$[1−4]. However, Nd:YLF has suffered problems of internal defects, which often lead to laser-induced bulk damage occurring before laser-induced surface damage[5,6]; meanwhile, stoichiometrically grown Nd:LuLF crystal has potential benefits for increased optical quality and appears to have the ability to mitigate these problems[7].

Nd:LuLiF_4, also known as Nd:LuLF which is isomorphic to Nd:YLF, was first grown by the national aeronautics and space administration (NASA) langley research center, and a 1047-nm laser was obtained through flash-lamp pumping, with slope efficiency of 1%[8−10]. In 1993, Alexander *et al*. have demonstrated room temperature oscillation of a laser-diode-pumped continuous-wave (CW) 1047-nm laser based on Nd:LuLF crystal with slope efficiency of 9.2% and an output power of 8 mW[11]. However, in their experiment, because of the limitation of technologies at that time, a single AlGaAs diode at 805 nm was adopted as pump source, which did not match the highest absorption. At present, Nd:LuLF has been grown domestically using the Czochralski technique by the key laboratory of materials for high power laser, Shanghai Institute of Optics and Fine Mechanics (SIOM). Hence, it is important to explore the lasing characteristics of the abovementioned crystal. Polarized absorption and emission spectra for the σ and π axes at 300 K are measured, as shown in Figs. 1(a) and (b), respectively.

In this letter, a compact 1047-nm all-solid-state laser based on Nd:LuLF crystal is demonstrated. With an incident pump power of 7.5 W, laser output of up to 1.3 W is obtained, while the optical-to-optical conversion efficiency is greater than 17%.

The experimental setup of the 1047-nm laser is shown in Fig. 2. Typical end-pumping configuration was used for the lasing experiment. A 792-nm fiber-coupled laser diode (LD) with spectral bandwidth of about 2 nm and the fiber having a core diameter of 400 μm and numerical aperture of 0.22 was used as the pump source for CW operation. The central wavelength can be slightly adjusted by changing the temperature to match the strongest absorption near 792 nm. The coupling optics, which consists of two identical plano-convex lenses with focal length of 18 mm at a ratio of 1:1, was used to adjust the spot size on the facet of the Nd:LuLF crystal. A simple linear plane-plane resonator with cavity length of about 25 mm was used. The rear mirror was coated with high transmission at 790 nm and high reflectivity at 1047 nm ($R > 99.5\%$). Two different types of coated mirrors were used as the output coupler; one mirror was coated with 5% transmission, while the other was coated with 10% transmission, both at 1047 nm. In our experiment, the 1% doped Nd:LuLF crystal, with a

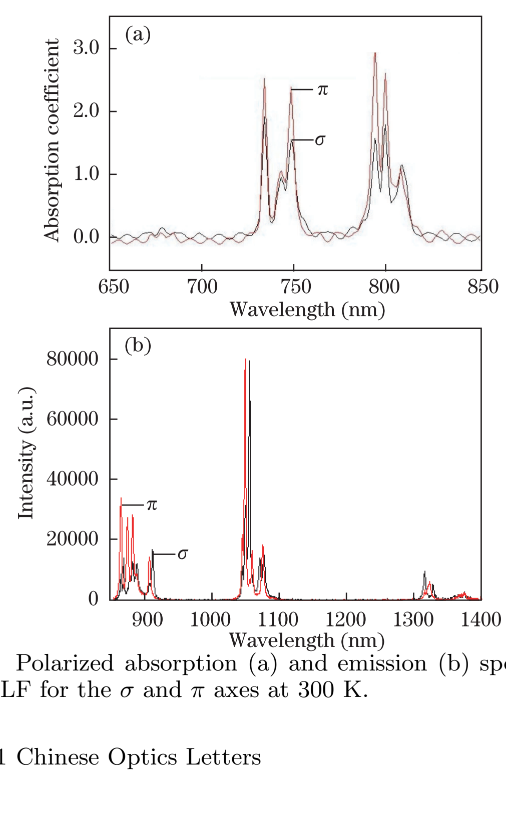

Fig. 1. Polarized absorption (a) and emission (b) spectra of Nd:LuLF for the σ and π axes at 300 K.

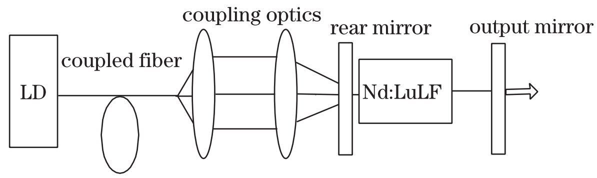

Fig. 2. Experimental setup of the 1047-nm laser system.

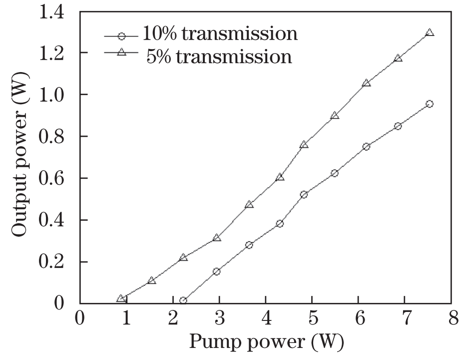

Fig. 3. Nd:LuLF laser output power versus pump power at different output couplers.

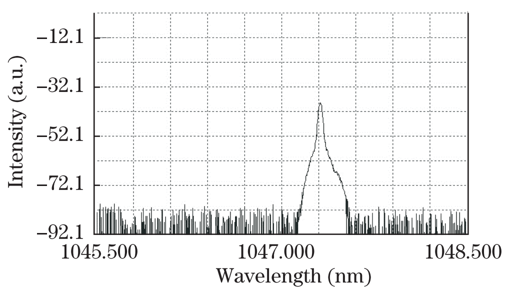

Fig. 4. Spectral profile of the 1047-nm laser.

dimensions of 3 × 3 × 4 (mm), was coated with high transmission at wavelengths of 790 and 1047 nm on both faces. The Nd:LuLF crystal was mounted on a water-cooled heat sink located close to the rear mirror.

Figure 3 shows the lasing characteristics of the emission of the 1047-nm laser using different output couplers. As can be seen, the lasing performance when a 5% transmission output coupler was used is better than that with 10% transmission. Compared with the 5% transmission, the 10% transmission indicates more intracavity losses, which will lead to a decrease in intracavity energy. As a result, the threshold will increase and the output power will decrease accordingly.

When the transmission of the output coupler is 5%, a slope efficiency of 20.1% with respect to incident pump power can be achieved. The effective absorption coefficient of the laser crystal at 792 nm is 1.3/cm, thus a slope efficiency of 49.5% can be obtained with absorbed pump power. Due to the negative thermal lens effect of the Nd:LuLF crystal and the instability of the resonator, slope efficiency is restricted. The spectral profile measured by the AQ6370B optical spectrum analyzer manufactured by Yokogawa Electric Corporation is shown in Fig. 4, which indicates that the central wavelength is about 1047.3 nm and the linewidth (full-width at

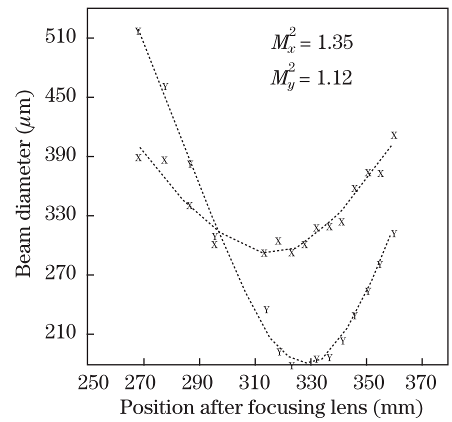

Fig. 5. Beam diameter versus position after focusing lens for determining beam quality.

half-maximum) is less than 0.3 nm. The beam-propagation factor M^2 of the 1047-nm laser is measured by the Spiricon M^2–200 beam propagation analyzer, which is shown in Fig. 5. When the output power is 1.3 W, M_x^2 and M_y^2 are measured as 1.35 and 1.12, respectively.

In conclusion, a compact all-solid-state 1047-nm laser based on Nd:LuLF crystal is developed. An output power of 1.3 W can be obtained from the laser system, which corresponds to a slope efficiency of 20.1% and 49.5% with respect to incident and absorbed pump power, respectively. Since the resonator is not optimized, there is still potential to improve the performance of the laser system. Nevertheless, to the best of our knowledge, this is the highest power level achieved at 1047 nm based on Nd:LuLF.

References

1. H. Y. Shen, R. F. Wu, Z. D. Zeng, W. X. Lin, R. R. Zeng, Y. P. Zhou, G. F. Yu, and C. H. Huang. Chinese J. Lasers **B9,** 103 (2009).
2. W. T. Hu, F. Z. Zhou, Y. M. Chen, and Z. H. Jiang, Acta Opt. Sin. **15,** 983 (1995).
3. M. Schmidt, E. Heumann, C. Czeranowsky, and G. Huber, in *Proceedings of CLEO* CThCl (2001).
4. I. R. Martín, Y. Guyot, M. F. Joubert, R. Yu, Abdulsabirov, S. L. Korableva, and V. V. Semashko, J. Alloys Compd. **323-324,** 763 (2001).
5. H. Vanherzeele, Appl. Opt. **27,** 3608 (1988).
6. G. F. Albrecht, M. T. Gruneisen, and D. Smith, IEEE J. Quantum Electron. **21,** 1189 (1985).
7. I. R. Harris, H. Safi, N. A. Smith, M. Altunbas, B. Cockayne, and J. G. Plant, J. Mater. Sci. **18,** 1235(1983).
8. N. P. Barnes, B. M. Walsh, K. E. Murray, and G. J. Quarles, in *Advanced Solid State Lasers*, *OSA Trends in Optics and Photonics Series* **10,** 448 (1997).
9. N. P. Barnes, B. M. Walsh, K. E. Murray, G. J. Quarles, and V. K. Castillo, J. Opt. Soc. Am. B **15,** 2788 (1998)
10. T. Y. Fan and R. L. Byer, IEEE J. Quantum Electron. **24,** 895 (1988).
11. A. A. Kaminskii, U. Ken-ichi, and U. Noboru, Jpn. J. Appl. Phys. **32,** L586 (1993).