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2.23 W diode-pumped Nd : YVO_4/LBO Laser at 671 nm

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Abstract

A fiber-coupled diode-array-pumped, intracavity frequency doubled by a LBO crystal, high-power Nd : YVO_4 red laser at 671 nm has been developed in this paper. With incident pump power of 10.6 W, employing a type-I critical phase-matched LBO crystal, 2.23 W single-transverse-mode red light at 671 nm was obtained, with optical-to-optical conversion efficiency up to 21.0%.

Keywords: LBO; Frequency conversion; Red laser

1. Introduction

Watt-level high-power diode-pumped compact visible lasers have recently attracted much attention and they have eventually become commercially available for a variety of practical applications. Multi-watt green lasers are used in ophthalmology, printing, entertainment, and for pumping Ti:Sapphire laser system. Blue lasers are mainly attractive for high-density data storage, and together with green and red lasers, for high-brightness color display or laser TV. The advanced technology of high-power red semiconductor laser array presently can offer multi-watt red laser in the 660–690 nm ranges, but the beam quality general gets worse. Although most of the applications requiring CW red lasers can be dealt with relatively inexpensive high-power diodes, in some cases a compact and high-performance solid-state replacement of a Kr-ion laser is preferred for generating a diffraction-limited and sometimes also narrow-line red beam.

An alternative approach to generate high beam quality, high-power red light is the intracavity doubling of a Nd : YVO_4 laser operating at a secondary transition of 1342 nm [1]. There are already some papers on diode-pumped 671 nm red lasers [2–5]. Among them, with a fiber-coupled 10 W diode array, Zhang et al. used type-II KTP to achieve 671 nm output of about 70 mW [2]; also Zhang et al. used type-I NCPM LBO ($T \approx 5°C$) and a V-shaped folded cavity to obtain 502 mW output, with optical-to-optical conversion efficiency up to 8.3% [3]; Agnesi et al. used type-II NCPM LBO ($T \approx 38°C$) and a V-shaped folded cavity to obtain 430 mW output [4]; We got optical-to-optical conversion efficiencies of up to 12.1% with type-I CPM LBO and drew a conclusion that type-I CPM LBO is best option for 1342 nm frequency doubling to obtain 671 nm output in diode-pumped Nd : YVO_4 red lasers [5].

In this paper, a diode-array-pumped Nd : YVO_4 laser operating at 1342 nm and intracavity frequency doubled by LBO to generate high-power red light 671 nm has been developed. With incident pump laser of 10.6 W, employing a type-I critical phase-matched LBO crystal, CW red laser at 671 nm as much as 2.23 W in single-transverse-mode was obtained, with optical-to-optical conversion efficiency of up to 21.0%. To our knowledge, this is the highest power achieved in diode-pumped diffraction-limited red lasers.

2. Experiment and results

The experimental setup is shown in Fig. 1. A 5 mm-long 0.5 atm%-doped a-cut Nd : YVO_4 crystal (CASIX Inc.) was coated for high transmission (HT) at 809 nm and high reflectivity (HR) at 1342 nm on one side as one resonator mirror (M_1), while the other side was antireflection (AR) coated at 1342 nm. The fiber-coupled diode array (LIMO,

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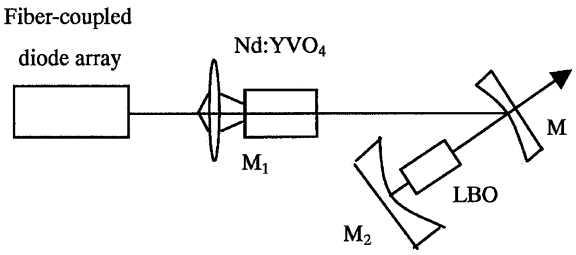


Fig. 1. Setup of a diode-pumped Nd : YVO_4/LBO red laser.

HLU12F, 400 μm fiber core diameter, N.A. = 0.22) emitted up to 10.6 W at 809 nm was used as pumping source and was focused to an approximately 380 μm-diameter spot inside the Nd : YVO_4 crystal, which was wrapped in a thin indium foil and mounted in copper holder. A 12 mm-long type-I CPM LBO crystal (θ=86.1°, φ=0°) coated 1342 AR and 671 nm AR on both sides was used for intracavity frequency doubling at 1342 nm.

In Fig. 1, the resonator is a V-shaped folded cavity. The mirror M_2 with curvature of 200 mm, was HR at 1342 nm ($R > 99.8\%$) and at 671 nm, while for the mirror M with curvature of 50 mm was HR at 1342 nm ($R > 99.8$) and HT at 671 nm ($T > 95\%$). The folding angle at the mirror M was always smaller than 7° to reduce astigmatism.

Laser diode, Nd : YVO_4 and LBO were strictly temperature controlled by three thermoelectric coolers, in order to make the central wavelength emitted from the laser diode coincide with the absorption peak of Nd^{3+} in order to utilize the pumping light very well, to reduce thermal effect of Nd : YVO_4 crystal and to keep the phase-matching condition of LBO from changing with surroundings, respectively.

In agreement with ABCD computations [6], we got the maximum output of red laser at 671 nm on the condition of $M_1M = 63$ mm and $M_2M = 29$ mm. The typical mode radii (at $1/e^2$) in Nd : YVO_4 crystal and in the LBO were $\omega_1 =$ 148 μm and $\omega_2 = 56$ μm, respectively, which is consonant with mode design criteria for diode-pumped lasers [7], and the 12 mm-long LBO crystal was set at about 0.3 mm from M_2.

The experimental results, represented in the form of 671 nm output power versus incident pump power, are shown in Fig. 2. With incident pump power of 10.6 W, employing a type-I critical phase-matched LBO crystal, 2.23 W single-transverse-mode red light at 671 nm was obtained, with optical-to-optical conversion efficiency up to 21.0%. To our knowledge, this is the highest power achieved in diode-pumped diffraction-limited red lasers.

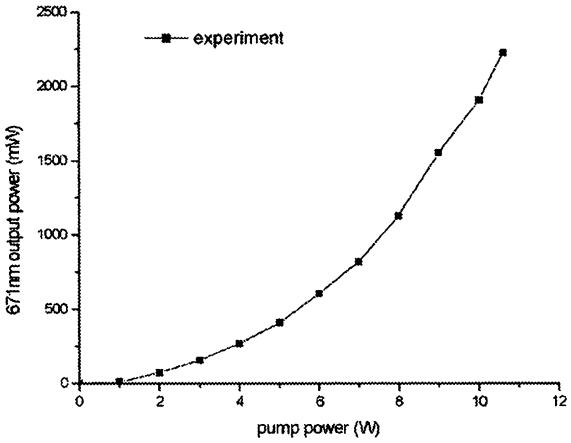
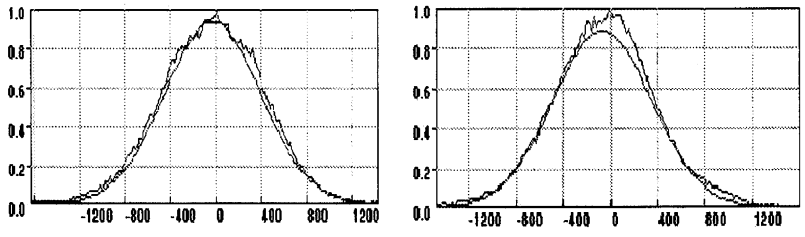


Fig. 2. 671 nm output power as a function of pump power.

The powerful output beam was characterized by a clean TEM_{00} mode ($M^2 < 1.2$). The TEM_{00} spatial energy distribution for the 671 nm laser in the far field was recorded by a beam profiler and is shown in Fig. 3. The polarization was linear, with the electric field oriented 90° with respect to the horizontal plane.

3. Conclusion

In conclusion, we have reported a compact diode-pumped red laser generating high-power single-transverse-mode red laser at 671 nm. With incident pump laser of 10.6 W, employing a type-I critical phase-matched LBO crystal, CW red laser at 671 nm as much as 2.23 W in single-transverse-mode was obtained, with optical-to-optical conversion efficiency of up to 21.0%. To our knowledge, this is the highest power achieved in diode-pumped diffraction-limited red laser. This compact high power and high performance all-solid-state laser will be a good choice



(a) (b)

Fig. 3. Spatial energy distribution for the 671 nm laser. (a) X direction, (b) Y direction.

for generating a diffraction-limited and sometimes also narrow-line red beam.

Acknowledgements

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