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LASERS
AND THEIR APPLICATIONS

All-solid-state Low Noise Yb:YAG/LBO Green Laser at 515 nm[1]

Liu Qianqian[a, b], Yang Min[a, b], Yao Yi[a, b], Zhao Ling[a, b], Li Bin[a, b], Qu Dapeng[a, b], and Zheng Quan[a, b]

[a] *Changchun Institute of Optics, Fine Mechanics and Physics, Chinese Academy of Sciences, Changchun Jilin, 130033 China*
[b] *Changchun New Industries Optoelectronics Tech. Co., Ltd. 130000 China*
e-mail: yaoyi@cnilaser.com

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Abstract—We report the efficient compact green laser at 515 nm generation by intracavity frequency doubling of a continuous wave (CW) laser operation of a diode-pumped Yb:YAG laser on the transition at 1030 nm. An LBO crystal, cut for critical type I phase matching at room temperature is used for second harmonic generation (SHG) of the laser. With the incident pump power of 10 W, 270 mW of CW output power at 515 nm is achieved with 15-mm-long LBO. The optical-to-optical conversion efficiency is 2.7%, and the power stability in 8 h is better than 2.36% with low noise.

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INTRODUCTION

With the emergence and quick development of InGaAs laser diodes which emit at the range of 900–1000 nm, Yb^{3+} doped lasers are becoming research interest because of its peak absorption around 940 nm [1]. The fluorescent spectrum of Yb:YAG crystal is quite wide with the peak emission of 1030 nm. The frequency doubling wavelength of 515 nm matches the highest power line of Ar-ion lasers, thereby leading to the possibility of an all solid-state replacement [2].

In Yb:YAG crystal, there is great re-absorption around 1030 nm, which makes it hard to oscillate under small pump density. By far, reports on 1030 nm laser mainly concentrate on high and middle power level [3]. To our best knowledge, the maximum optical-to-optical conversion efficiency of 515 nm laser was only 0.98% under the condition of low pump power and room-temperature continuous operation.

In this paper, we report the efficient compact green laser at 515 nm generation by intracavity frequency doubling of a continuous wave (CW) laser operation of a diode-pumped Yb:YAG laser on the transition at 1030 nm. An LBO crystal, cut for critical type I phase matching at room temperature, is used for second harmonic generation (SHG) of the laser. With the incident pump power of 10 W, 270 mW of CW output power at 515 nm is achieved with 10-mm-long LBO. The optical-to-optical conversion efficiency is 2.7%, and the power stability in 8 h is better than 2.36% with low noise.

[1] The article is published in the original.

EXPERIMENTAL SETUP

A schematic of the experimental setup is shown in Fig. 1. Three-mirror folded cavity configuration is adopted to achieve high efficiency. The laser is pumped by a single laser diode which has a beam diameter of 300 μm at its focus spot after the focusing lens. Adjust the temperature of the heat sink of the LD through thermoelectric controller to keep its peak emission wavelength at 940 nm. The maximum output power of the LD is 10 W.

The dimension of Yb:YAG crystal is $3 \times 3 \times 1$ mm^3, and doped with 10 at % Yb^{3+} ion. The left side of the crystal is highly reflection coated at 1030 nm and 515 nm, and highly transmission coated at 940 nm. The other side of the laser crystal is antireflection coated at 1030 nm and 940 nm. Transmission of output mirror M1 at 1050 nm is a little higher than 1030 nm in order to increase the loss of photons at 1050 nm. The curvature radius of output mirror M1 is 100 mm with the HR coated at 1030 nm, partial transmission coated at 1050 nm and AR coated at 515 nm

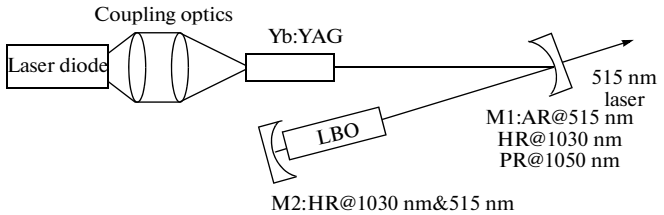

Fig. 1. The schematic of Yb:YAG laser.

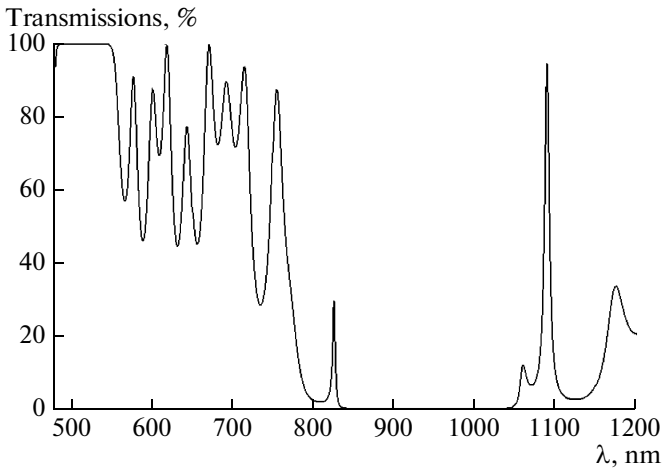

Fig. 2. Transmission of the output mirror at each wavelength.

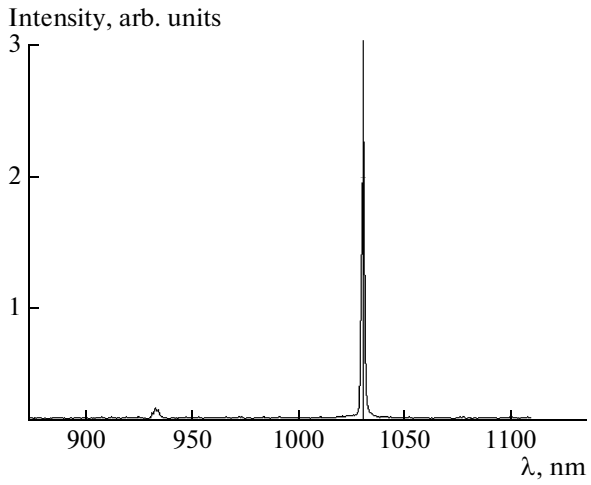

Fig. 3. The wavelength of fundamental beam at 1030 nm.

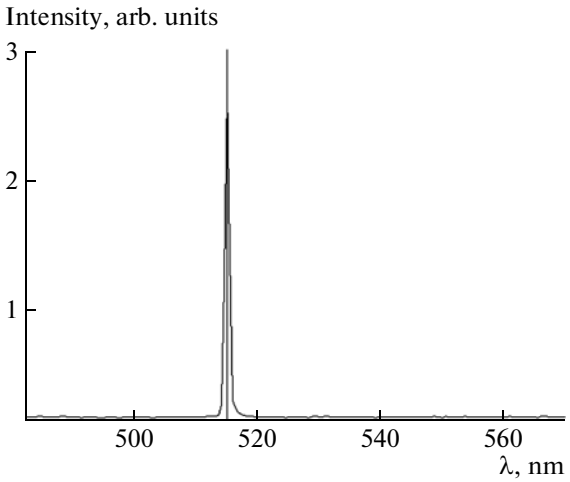

Fig. 4. The wavelength of harmonic beam at 515 nm.

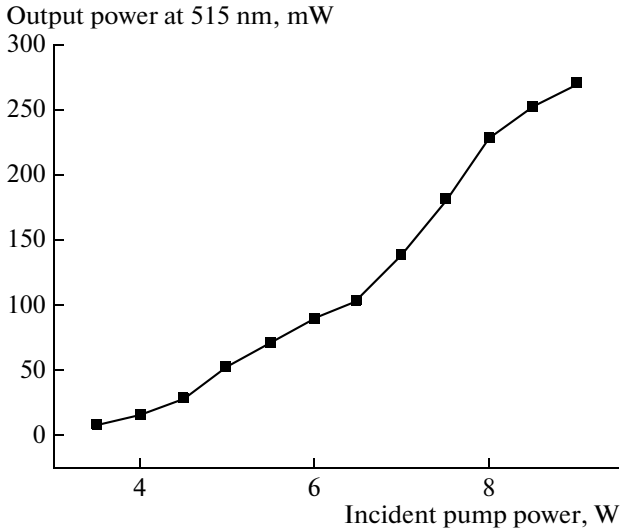

Fig. 5. The output power at 515 nm versus the incident pump power.

which is shown in Fig. 2. The curvature radius of the end mirror M2 is 200 mm and HR coated at 1030 nm and 515 nm. The dimension of LBO frequency-doubling crystal is $2 \times 2 \times 15$ mm^3, cutting at $\theta = 90°$ and $\varphi = 13.6°$, and is mounted on a copper heat sink for temperature control. A Brewster plate polarizer with the thickness of 1 mm is inserted into the cavity, and placed at Brewster's angle of 1030 nm.

RESULTS AND DISCUSSIONS

1030 nm and 515 nm laser oscillation can be obtained only if the doping concentration of Yb:YAG is 10% and the length is 1 mm. Thinner Yb:YAG crystal will crack at high pump power density, and thicker crystal or other doping concentration will lead to high re-absorption. The wavelength of the fundamental wave and harmonic wave are shown in Fig. 3 and Fig. 4 which are measured by Ocean Optics HR4000CG-UV-NIR spectrometer.

The output power of 515 nm laser versus the incident pump power is demonstrated in Fig. 5. The threshold of 515 nm laser was 3.5 W. With the increased of the incident power, inverse population accumulates at the upper laser level and the re-absorption of photons at lower level decreases. Therefore, the output power of 270 mW at 515 nm was obtained with the incident pump power of 10 W.

Figure 6 shows the beam profile of 515 nm laser and the M^2 factor is 1.15 and 1.19 in X and Y direction.

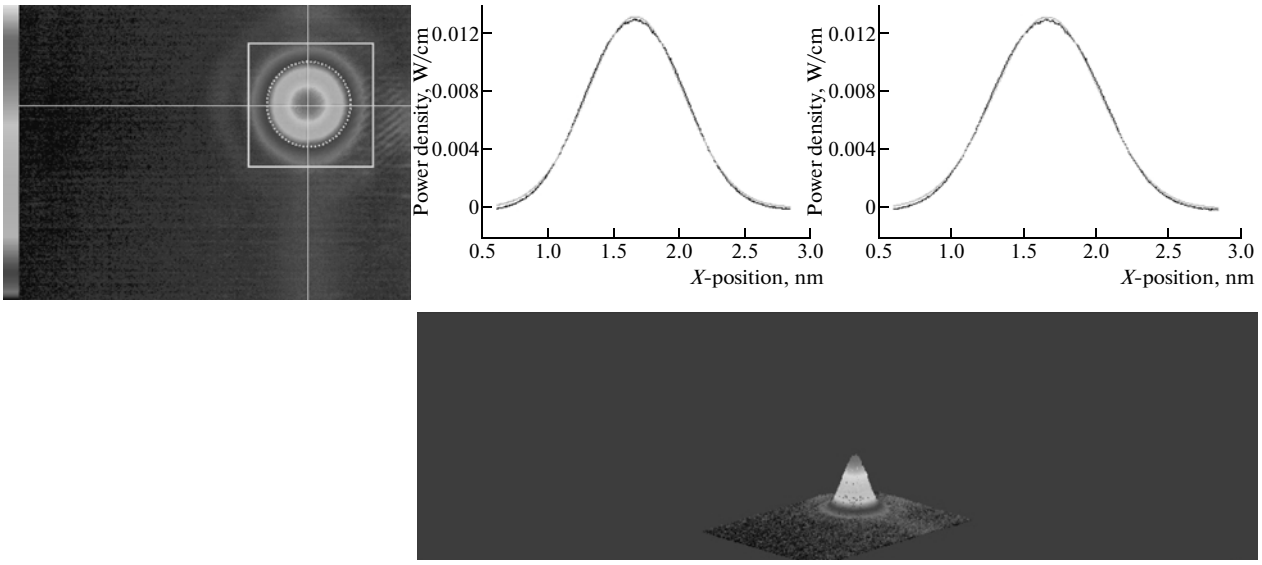

Fig. 6. Beam profile of 515 nm laser.

Since the Brewster plate polarizer is inserted into the cavity and placed at Brewster's angle of 1030 nm, some photons are reflected outside the cavity. For longitudinal modes at 1030 nm, there is only some loss with the electric vector that is perpendicular with the incident plane. However, for the other longitudinal modes, there are losses both on the direction of perpendicular and parallel electric vectors. So these modes are suppressed [4] and the competition between longitudinal modes decreased which make the laser operates under the low noise state.

CONCLUSIONS

In conclusion, we report the efficient compact green laser at 515 nm generation by intracavity frequency doubling of a continuous wave (CW) laser operation of a diode-pumped Yb:YAG laser on the transition at 1030 nm. An LBO crystal, cut for critical type I phase matching at room temperature is used for second harmonic generation (SHG) of the laser. With the incident pump power of 10 W, 270 mW of CW output power at 515 nm is achieved with 15-mm-long LBO. The optical-to-optical conversion efficiency is 2.7%, and the power stability in 8 h is better than 2.36% with low noise.

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