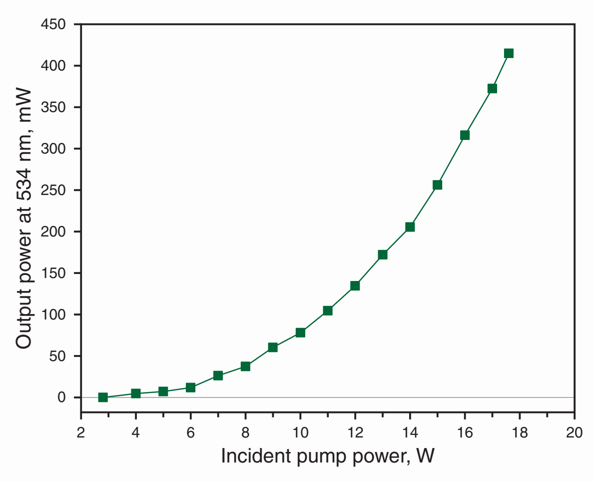
Abstract: A compact and efficient diode-pumped intracavity frequency-doubled $Yb^{3+}:SrY_4(SiO_4)_3O$ (Yb:SYS) green laser at 534 nm is demonstrated. With 17.6 W of diode pump power and the frequency doubling crystal LiB_3O_5 (LBO), a maximum output power of 415 mW in the green spectral range at 534 nm has been achieved, corresponding to an optical-to-optical conversion efficiency of 2.4%; the output power stability over 4 hour is better than 3.5%. To the best of our knowledge, this is first work on intracavity frequency doubling of a diode pumped Yb:SYS laser at 1068 nm.



Output power at 534 nm *versus* pump power

Diode-pumped frequency-doubled Yb:SYS-LBO green laser at 534 nm

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Key words: diode-pumped; solid-state laser; Yb:SYS crystal

1. Introduction

Within the past few years, Yb^{3+}-doped materials have attracted considerable research interest as promising active media for all-solid-state high-power lasers. This is due mainly to the fact that the simple energy level scheme of Yb^{3+} minimizes undesirable effects such as upconversion, excited-state absorption, and concentration quenching. Also, the small quantum defect (5–15%) and high quantum efficiency reduce the thermal load and associated problems [1]. Another important advantage of Yb^{3+}-doped laser crystals over the Nd^{3+}-doped counterparts is their broadband fluorescence. The laser performance of Yb^{3+}-ions has been reported in Yb:YAG, Yb:KYW, Yb:LSO, Yb:YSO, etc. [2–50]. The $Yb^{3+}:SrY_4(SiO_4)_3O$ (Yb:SYS) crystal is very interesting crystals thanks to better spectroscopic properties (higher emission cross section and broader emission band) [51–53] and its better thermal conductivity [54].

Fig. 1 shows the absorption and emission spectra of the Yb:SYS along the π and σ axes [55]. The emission spectrum is smoother along the π axis (polarization $\|\mathbf{c}$) than along the σ axis (polarization $\perp\mathbf{c}$). In 2004, F. Druon et al. realized the pulses centered at 1070 nm Yb:SYS laser for the first time [56]. In the same year, F. Druon et al. report the shortest pulses ever produced with an Yb:SYS laser. An average power of 156 mW has

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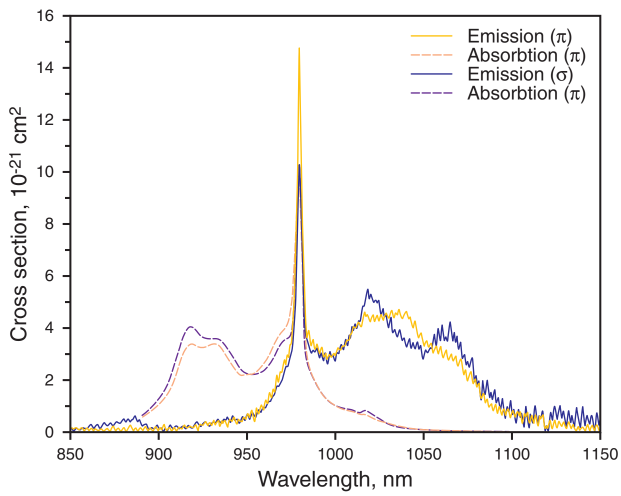

Figure 1 (online color at www.lphys.org) Absorption and emission spectra of the Yb:SYS along the π and σ axes

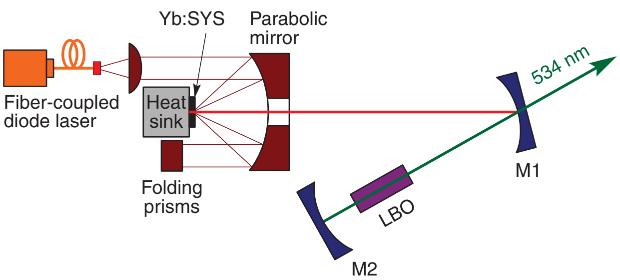

Figure 2 (online color at www.lphys.org) Experimental setup of the frequency-doubled Yb:SYS-LBO green laser at 534 nm

been obtained at 1066 nm. Moreover, an average power of 420 mW has been obtained at 1068 nm [55]. To the best of our knowledge, the corresponding frequency doubled green lasers have not been reported. In this Letter, an efficient continuous wave (CW) 534 nm intracavity frequency-doubling green laser based on diode pumped Yb:SYS/LBO is demonstrated. With an incident pump power of 17.6 W, up to 415 mW of green laser emission at 534 nm is achieved. The optical conversion efficiency is 2.4% with respect to the incident pump power.

2. Experimental setup

The experimental setup used is described in Fig. 2. The optical pumping at 980 nm was realized with a fiber coupled diode laser. The maximum CW output power delivered by this prototype diode was 20 W and the width of the emission spectrum was $\sim$2.5 nm. The optical fiber of diode had a diameter of 400 μm and a numerical aperture of NA = 0.22. The experiment was performed with a

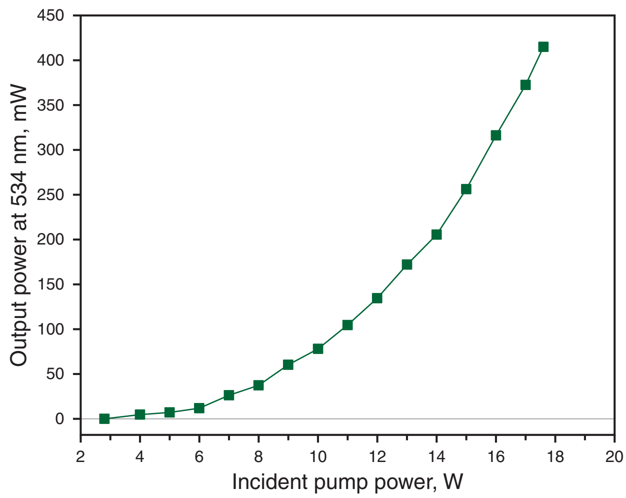

Figure 3 (online color at www.lphys.org) Output power at 534 nm *versus* pump power

5.5%-doped, 0.3 mm thickness. The crystal was cut to have the propagation axis perpendicular to **c**, which allowed to have the laser polarized $\|$**c**. The thin-disk crystal was antireflection (AR)-coated at the front side and high-reflection (HR)-coated at the rear side for pump and laser wavelengths. The rear side was soldered onto a water-cooled heat sink with a coolant temperature maintained at 15°C. The parabolic mirror (32 mm focal length) and the folding prisms lead to a 16-pass pump scheme. The radii of curvature of mirror M1 was 200 mm. The radii of curvature of mirror M1 was 50 mm. M1 is an output coupler, which was AR coated at 534 nm and HR at 1068 nm. The radius of curvature of mirror M2 was 200 mm. M2 was HR coated at 534 nm and 1068 nm. The distances S1 – M1, S1 – M2, and M2 – M3 were 55, 67, and 28 mm, respectively. The generation of green light was achieved by using a 10 mm long LiB_3O_5 (LBO) nonlinear crystal, which was cut for type I phase matching ($\theta = 90°$, $\Phi = 11.1°$) at room temperature. The LBO crystal, which had both surfaces AR coated for 1068 and 534 nm, was inserted into the M2 – M3 arm of the V-type resonator.

3. Experimental results

The output power at 534 nm *versus* the incident pump power is shown in Fig. 3. With an incident pump power of 17.6 W, we recorded an oscillation threshold at 2.8 W, and a CW green output power of 415 mW at 534 nm has been obtained.

Fig. 4 shows the shape of 534 nm green light spot at pump power of 17.6 W. The beam profile in Fig. 5 was measured at pump power of 17.6 W using the beam profiler (made by Photon Inc.). The beam profile was measured to be TEM_{00} and the ellipticity of spot is 0.96. The

Figure 4 (online color at www.lphys.org) The beam shape of green laser at 534 nm

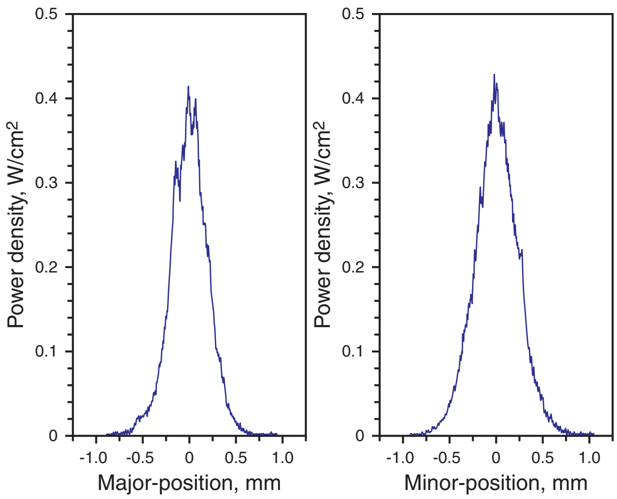

Figure 5 (online color at www.lphys.org) Beam profile distribution of 534 nm green laser

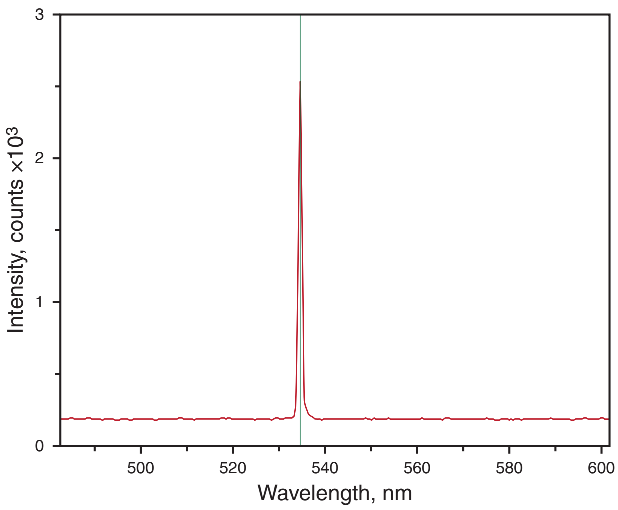

Figure 6 (online color at www.lphys.org) The laser spectrum line of 534 nm laser

green power stability was investigated by a Field-Master-GS powermeter and the fluctuation was about 3.5% at the maximum output power in 4 hour. Fig. 6 shows the spectra of green output power of 415 mW, which was detected using the high resolution spectrometer.

4. Conclusion

In summary, an efficient green laser at 534 nm generated by intracavity frequency doubling of the CW laser output of a diode-pumped Yb:SYS laser at 1068 nm. With a 17.6 W diode pump power and the frequency-doubling crystal LBO, a maximum output power of 415 mW in the green spectral range at 534 nm has been achieved, corresponding to an optical conversion efficiency of 2.4%, and the output power stability over 4 hour is better than 3.5%. Moreover, the output 534 nm green power could again be increased by using more efficient non-linear crystals or by using a more powerful pump power.

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