Study on the Pr:KYF ultraviolet laser at 305 nm pumped by blue laser*

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An all-solid-state Pr:KY_3F_{10} (Pr:KYF) laser pumped by blue laser (471 nm) has been demonstrated. With the incident pump power of 2.6 W, the maximum output power at 610 nm is 213 mW. Moreover, the intracavity second-harmonic generation (SHG) is also achieved with the maximum ultraviolet (UV) power at 305 nm of 11 mW by using a β-BaB_2O_4 (BBO) nonlinear crystal.

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Ultraviolet (UV) light sources of solid-state lasers based on nonlinear optical frequency conversion are in high demand for various applications in science and industry because of their compactness, narrow spectral width and reliability. In the past 20 years, extensive efforts toward the development of nonlinear optical crystals have been made to produce such a laser by means of frequency conversion of high-power solid-state lasers. Most of the researches on the UV radiation have been focused on pulse lasers[1-4], but only a few works about the continuous wave (CW) UV radiation were reported[5]. However, the CW UV source is expected to have applications in many areas, such as next-generation ultrahigh-density optical disk mastering, photolithography and material processing[6-10]. In 1995, the highest power level in CW UV generation was obtained using BaB_2O_4 (BBO) crystals in the fourth harmonic generation stage, which achieved up to 1.5 W at 266 nm[11]. In 2000, Tetsuo Kojima et al[12] reported the 20 W ultraviolet-beam generation by the fourth harmonic generation of an all-solid-state laser. In 2003, a solid-state OPO-Nd:YAG laser ablation system at 193 nm is evaluated and designed[13]. In 2007, the efficient fourth harmonic UV generation of passively Q switched Nd:$GdVO_4$/Cr^{4+}:YAG lasers has been reported[14]. After that, in 2010, B. T. Zhang et al[15] reported that CW UV laser at 355 nm with average power of 7.8 W is obtained from an efficient and compact intracavity frequency tripled Nd:YAG laser.

The laser crystal is one of the most important components of a solid-state UV laser. In recent years, Pr^{3+} doped crystals, glasses and fluorides[16] with more efficient radiative transitions can be used for producing multicolor laser emissions for red, green and blue light applications. In this paper, we report an all-solid-state Pr:KY_3F_{10}(Pr:KYF) laser at 610 nm pumped by blue laser. Moreover, we also examine intracavity second-harmonic generation (SHG) to obtain the UV light at 305 nm.

The experimental setup of the fundamental laser at 610 nm is shown schematically in Fig.1(a). Blue solid-state laser sources based on the frequency-doubling have been reported in the recent years[17-19]. The pump source is an all-solid-state CW frequency-doubled Nd:GSAG-LBO blue laser, which can provide the laser with power of nearly 2.8 W at 471 nm. This blue laser was first proposed by Y. L. Li et al[20]. In our experiment, F is a focus lens with the focal length of 70 mm, which is used for enhancing the density of pump power and obtaining better volume matching between the pump and oscillating beams. The pump beam is focused into the Pr:KYF crystal with a waist spot radius of around 65 μm. A Pr:KYF crystal (5 mm long) with doping concentration of 0.4 at.% is chosen in the experiment. Both surfaces of the Pr:KYF crystal are coated for antireflection (AR) at 471 nm and 610 nm. The Pr:KYF crystal is wrapped with inindium foil and clamped in a copper holder while the water temperature is kept at 15°C. The plane mirror (M1) of the cavity is antireflective (AR) at 471 nm and highly reflective (HR) at 610 nm. The output coupler (M2) with the radius of curvature of 50 mm is used, whose transmission is 3.4% at 610 nm. The distance between M1 and M2 is 24 mm.

Schematic diagram for the intracavity frequency-doubled

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laser at 305 nm is shown in Fig.1(b). The output mirror M3 with radius of curvature of 50 mm is HR at 610 nm and AR at 305 nm. The distance between M1 and M3 is 22 mm. The BBO crystal which is cut for type-I critical phase matching in the principal plane *XY* (θ = 90° with eff_d =1.89 pm/V) is chosen as the nonlinear crystal due to its high anti-damage threshold and much smaller walk-off angle. The size of the BBO crystal is 3 mm × 3 mm × 4 mm, and both end facets of the BBO crystal are coated for AR at 610 nm and 305 nm to reduce the reflection losses in the cavity.

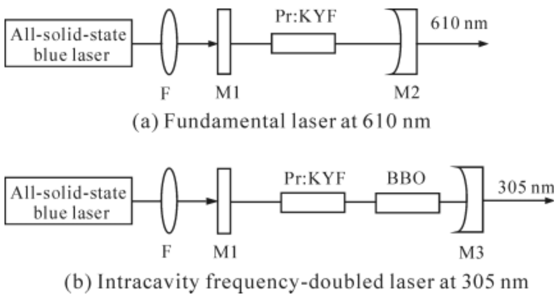

Fig.1 Schematic diagrams of the experimental setup

The laser performance is presented in Fig.2. The laser threshold of incident pump power is 0.4 W. With the incident pump power of 2.6 W, the maximum output power is 213 mW for the laser at 610 nm.

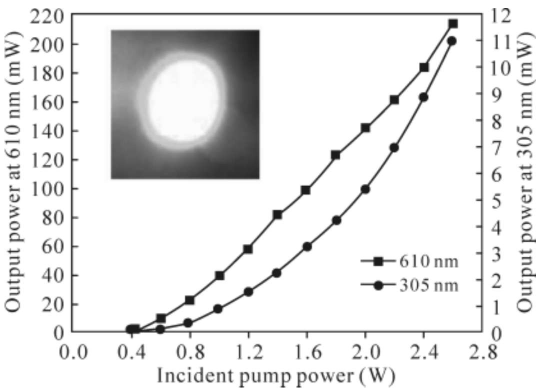

Fig.2 Output power versus incident pump power (The inset is the beam shape of ultraviolet laser at 305 nm.)

With the incident pump power of 2.6 W, the CW SHG total output power of 11 mW at 305 nm UV emission is obtained. The system emits nearly TEM_{00} mode with beam quality factor of 1.24 measured by the knife-edge technique. The inset of Fig.2 shows the shape of 305 nm UV laser beam at pump power of 2.6 W. The fluctuation of the output power is about 4.3% in 30 min as shown in Fig.3. And Fig.4 shows the spectrum of the laser at 305 nm which is detected using the spectrometer with high resolution.

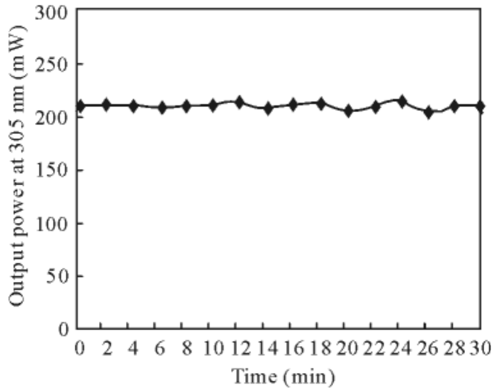

Fig.3 Fluctuation of the output power in 30 min

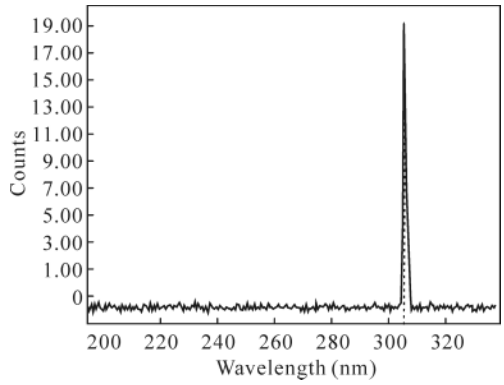

Fig.4 Spectrum of the ultraviolet laser at 305 nm

In conclusion, we succeed in the realization of an all-solid-state intracavity frequency-doubled Pr:KYF-BBO laser at 305 nm, which is pumped by blue laser. For the 610 nm emission, a CW laser with output power of 213 mW is achieved. After the SHG, the maximum power of 11 mW at 305 nm is obtained. Thus, this demonstration opens a new way to obtain UV light. More efficient nonlinear conversion could also be obtained by using more efficient nonlinear crystals.

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