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430nm DPSS blue laser generated by sum-frequency mixing

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ABSTRACT

An all-solid-state blue laser at 430nm generated by intracavity sum-frequency mixing of a Nd: YAG laser emitting at 1319nm and a Pr:YLF laser at 639.5nm is presented. The continuous output power of 430nm is over 190mW which is the highest laser power emitting at this wavelength according to current report. The Nd: YAG and Pr:YLF crystal was pumped by a 5.9W 808nm and a 3.0W 444nm laser diode respectively. The optical-to-optical conversion efficiency is 2.1%.

1. Introduction

In recent years, laser light sources in the visible region is required by the fields of biomedicine, display technology, communications etc. In particular, the blue lasers among them are quite important for many applications including information storage, spectroscopy and optical image. So they are attracting a lot of researchers [1].

Before the development of all-solid-state laser technology, 430 nm blue laser is primarily diode laser pumped by electricity which has large beam divergence angle, and the directionality and monochromaticity are not so good [2,3]. Researchers have found other ways to get the blue light at 430 nm such as generating by intracavity frequency doubling from LD end pumped Cr:LiSAF laser through critical phase matching of BBO [4]. Unfortunately, thermal effects in Cr:LiSAF have shown to be the limiting factor for further power scaling resulting in a low power. So there need to be an alternative way to get this laser.

In this report, we present a 430 nm blue laser using an intracavity sum-frequency generation by a nonlinear crystal LBO and experimentally achieve a high continuous-wave output power of 190 mW. It is a novel and efficient way to get the wavelength.

As the quantum theory, the sum-frequency generation can be described as the annihilation of photons $\hbar\omega_1$ and $\hbar\omega_2$, and the creation of a photon $\hbar\omega_3$, so that

$$\hbar\omega_1 + \hbar\omega_2 = \hbar\omega_3 \quad (1)$$

where ω_1 and ω_2 are frequencies of two light sources and ω_3 is the sum-mixing frequency.

Meanwhile the momentum conservation is

$$\hbar\vec{\kappa_1} + \hbar\vec{\kappa_2} = \hbar\vec{\kappa_3} \quad (2)$$

where $\vec{\kappa_i}$ is the wavevector and this equation also demonstrates the phase-matching condition. With I-type noncritical-phase-match Lithium Triborate(LBO), the efficiency of SFG can be greatly enhanced because the phase-matching condition is met.

The scheme of experimental setup of sum-frequency 430 nm laser is shown in Fig. 1. LD1 and LD2 are laser diode emitting at 808 nm and 444 nm separately. The two pairs of plano-convex lenses focus the pump beam into laser crystals. C1 was the laser crystal Nd: YAG [5–8] with high reflection (HR) coatings at 1319 nm and antireflection (AR) coatings at 808 nm&914nm&1064nm&1338 nm. C2 was an a-cut Pr:YLF crystal [9–13] with AR@444 nm &HR@640 nm coatings on the pumping side. C3 is LBO which

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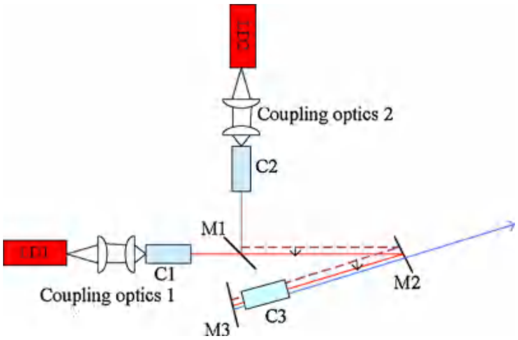

Fig. 1. Experimental setup.

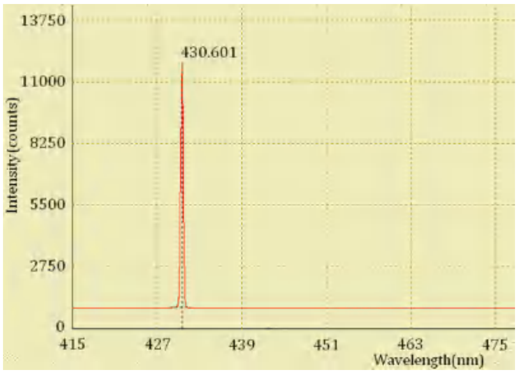

Fig. 2. Output spectrum of the blue laser.

makes a sum frequency of the fundamental laser. M1 is a 45° dichroic mirror with high reflectivity for 1319 nm and high transparency for the 640 nm laser. M2 and M3 have high reflection at both fundamental wavelength. They are output coupler and reflecting mirror respectively.

After the experiment, a Thorlabs' bandpass filter (FB430-10) which transmits the desired wavelength, while rejecting other radiation was used. Fig. 2 shows the emission spectrum of the blue laser measured by a fiber spectrometer (HR4000, Ocean Optics, Inc.) with a resolution of 0.02 nm. The spectrum at the maximum output power was a single line. The central wavelength is 430.601 nm.

According to test report of FB430-10, the filter has a transmission of 46.6% at 430.601 nm. The power meter readings should be divided by 46.6% to give the final output power. The results are shown in Fig. 3. The pump thresholds of the laser were measured to

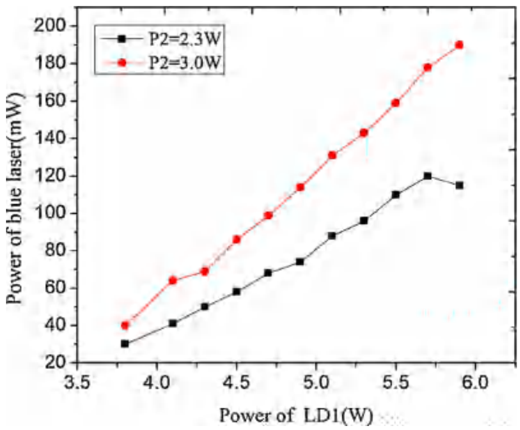

Fig. 3. Output power of blue laser vs pump power.

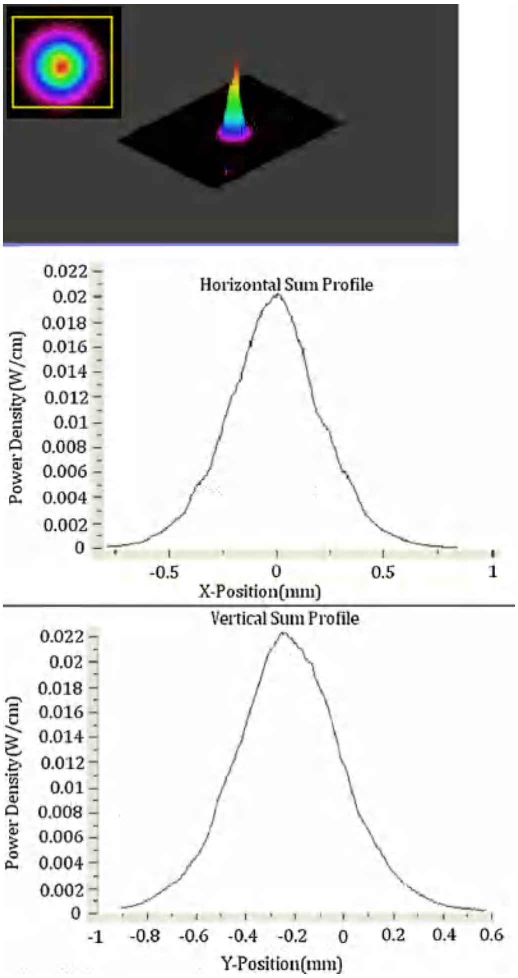

Fig. 4. Intensity profile of the laser output.

be 3.3 W for 1319 nm and 1.9 W for 640 nm, respectively. The black dots represent the measured experimental powers at 430.601 nm by increasing current of LD1 with the power of LD2 fixed at 2.3 W. The black line shows the simulated result.

The red dots were measured at the largest power of LD2. A maximum output power of 190 mW was obtained when 5.9 W LD1. The power stability of the laser was better than 2.9% in 8 h.

The beam intensity profile of the 430 nm laser at the maximum output power was measured by a Laser Beam Analysis System (Ophir Spiricon SP620U) as is shown in Fig. 4. The two dimensional and three dimensional distributions indicate a Gauss-like beam profile. The M^2 factors were approximately 1.82 and 1.70 in the horizontal and vertical directions. The asymmetry of M^2 factors in the two directions is a result of walk-off between the fundamental wave and the sum-frequency wave in direction of LBO.

In conclusion, an all solid-state sum-frequency laser at 430.6 nm was demonstrated. The continuous wave maximum output power of blue laser was 190 mW at the pump power of 5.9 W of 808 nm and 3.0 W of 444 nm. The wavelength, power stability and beam profile were measured. To our knowledge, it is the highest power of this wavelength and achieved by intracavity sum-frequency method for the first time. This laser has advantages of ultra compact, high efficiency, low cost and good beam quality.

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