Generation of blue laser by extracavity frequency-doubling of a tunable Ti:sapphire laser

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In this letter, a blue laser based on frequency-doubling of tunable Ti:Sapphire laser pumped by a frequency-doubled Q-switched Nd:YAG laser at a repetition rate of 10 Hz is demonstrated. A β-BaB$_2$O$_4$(BBO) crystal was used for frequency-doubling of the Ti:sapphire laser to obtain high efficiency second harmonic generation (SHG). By using two dense flint glass prisms as dispersion element, a Ti:sapphire laser and blue laser with tuning range from 740 nm to 860 nm and 370 nm 430 nm were obtained, respectively. At incident pump energy of 50 mJ, the maximum output energy was 7.2 mJ and 2.9 mJ at 800 nm and 400 nm, respectively.

(Received August 26, 2014; accepted November 13, 2014)

Keywords: Blue laser, Tunable Ti:Sapphire laser, Prism-dispersion

1. Introduction

Blue lasers are widely used in various fields such as underwater communication, medical research, color display, and so on. Frequency-conversion of solid-state NdP^{3+P} lasers is a popular way to obtain blue laser [1-3]. However, these type lasers always have a low efficiency because of the small NdP^{3+} ^{P}simulated-emission section and the large reabsorption loss due to the quasi-three-level operation. Furthermore, such lasers are not suitable for the generation of blue laser radiation at 370-450 nm because their wavelength is confined to 910-1100 nm. Ti:sapphire (Ti:AlB$_{2B}$OB$_{3B}$) has a unrivalled output spectral bandwidth, from about 660 to 1180 nm, which is the broadest tuning range for any single laser media. It has large stimulated emission cross section, high saturation energy and broad absorption gain bandwidth [4].

In this paper, a high-efficiency tunable Ti:sapphire laser pumped by a frequency-doubled Q-switched 532 nm Nd:YAG laser at a repetition rate of 10 Hz was demonstrated. Two dense flint glass prisms were used as dispersion element to reduce the laser linewidth, and at an incident pump energy of 50 mJ, the tunable Ti:sapphire laser from 740 to 860 nm was obtained with a linewidth of 0.8 nm (FWHM), including the maximum output energy of 7.2 mJ at 800 nm with a pulse width of 20.6 ns (FWHM). After frequency-doubling using BBO crystal, a blue laser with tuning range of 370-430 nm and maximum energy of 2.9 mJ at 400 nm was achieved.

2. Experimental setup

The schematic of tunable Ti:Sapphire laser and frequency-doubling blue laser is shown in Fig. 1. The pumping source was a frequency-doubled Q-switched 532 nm Nd:YAG laser at a repetition rate of 10 Hz. A convex focus lens with the focal length of 75 mm was used to enhance the density of pump energy therefore to decrease the threshold energy. The Ti:sapphire crystal with 10 mm diameter and 20 mm length, was cut at Brewster angle at both ends with respect to the direction of c axis for the highest absorption in the pumping 532 nm green light and the highest emission in the near infrared region. It was wrapped with thick indium foil and placed into a water-cooled copper heat sink. The input mirror MB$_{1B}$ had high reflection coating in the range of 750-850 nm. The output coupler MB$_{2B}$ was a flat mirror with a transmission of 45%. Two dense flint glass prisms as dispersion element were used in the laser cavity to narrow the output linewidth. The total cavity length was about 300 mm. The BBO crystal was used as the frequency-doubler. The dimensions were 6 mm×6 mm×7 mm and the cutting angle was selected at 29.2 degree for Type I, angle-tuned phase matching.

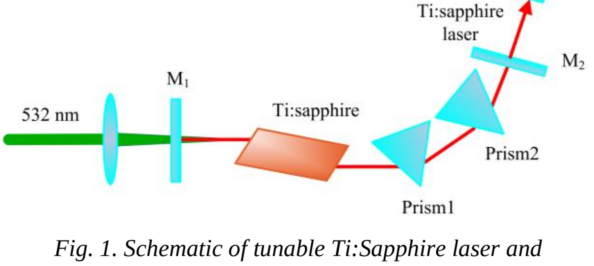

Fig. 1. Schematic of tunable Ti:Sapphire laser and frequency-doubling blue laser.

3. Experimental results and discussions

Firstly the tuning range of Ti:sapphire laser was investigated. When the incident pump energy of 532 nm laser was 50 mJ, by turning MB_{2B}, a tuning range from 740 nm to 860 nm with linewidth of 0.8 nm (FWHM) was obtained. The measured results are shown in Fig. 2. The maximum output energy was 7.2 mJ at 800 nm. Because the input mirror MB_{1B} didn't have high reflection coating in the range of 740-750 nm and 850-860 nm, the output energy in these ranges decreased rapidly.

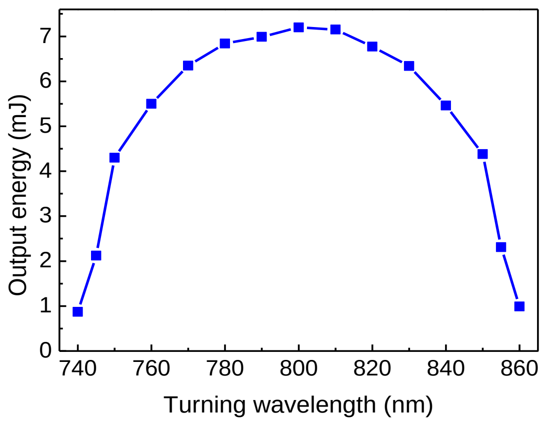

Fig. 2. Output energy as a function of laser wavelength at incident pump energy of 50 mJ

The output energy of Ti:sapphire laser at 800 nm as a function of incident pump energy is shown in Fig. 3. The slope efficiency is about 28.3%. Because Ti:sapphire has a short upper laser level lifetime of 3.2 μs and the insertion of two glass prisms into the laser cavity has relatively high losses [5], the laser had high threshold energy of 24.8 mJ.

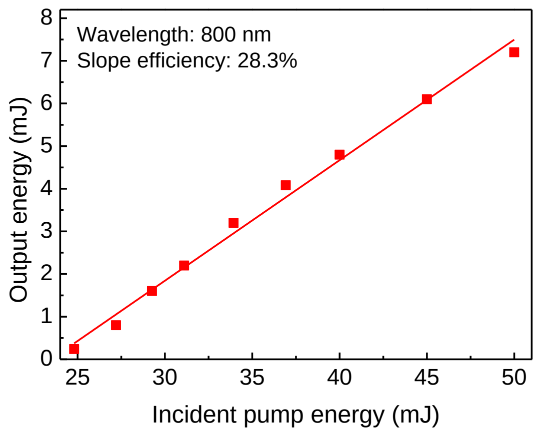

Fig. 3. Output energy as a function of incident pump energy at 800 nm.

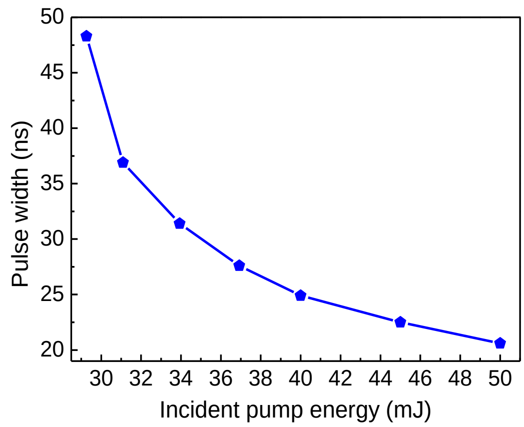

Fig. 4. Pulse width as a function of incident pump energy at 800 nm wavelength.

The pulse width as a function of incident pump energy at wavelength of 800 nm is shown in Fig. 4. The pulse width decreased with increasing of incident pump energy. The minimum pulse width is 20.6 ns when the pump energy is 50 mJ.

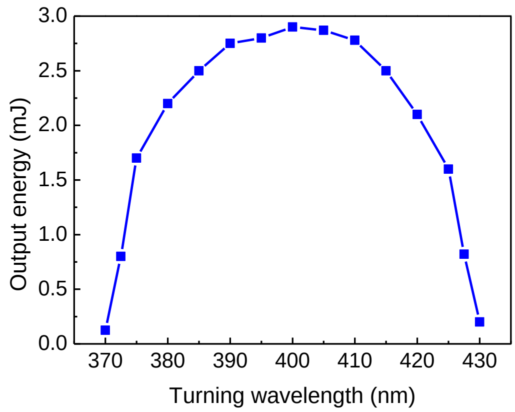

Fig. 5. Output energy for the tunable blue laser from 370 nm to 430 nm.

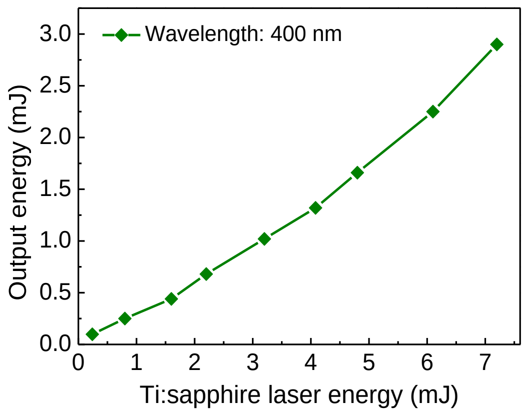

Fig. 6. Output energy of blue laser at 400 nm as a function of Ti:sapphire laser energy.

When the incident pump energy of 532 nm laser was 50 mJ, by rotating the BBO crystal in the range of ±5 degree around the cutting angle of 29.2 degree in the horizontal direction and turning the mirror MB_{2B}, tunable blue laser from 370 nm to 430 nm was obtained, as shown in Fig. 5. The maximum output energy was 2.9 mJ at 400 nm with a frequency-doubling efficiency of 40.3%. The output energy of blue laser at 400 nm as a function of Ti:sapphire laser energy is shown in Fig. 6.

4. Conclusions

In conclusion, a tunable blue laser based on frequency-doubling of Ti:Sapphire laser was demonstrated successfully. For the tunable Ti:Sapphire laser, a tuning range of 740-860 nm with a linewidth of 0.8 nm was obtained with the help of two glass prisms used as dispersion element. At an incident pump energy of 50 mJ, the maximum output energy was 7.2 mJ at 800 nm with a pulse width of 20.6 ns, and the corresponding slope efficiency was 28.3% for the 532 nm pump laser to the Ti:sapphire laser. After frequency-doubled with nonlinear crystal BBO, tunable blue laser from 370 nm to 430 nm was realized containing the maximum output energy of 2.9 mJ at 400 nm with a frequency-doubling efficiency of 40.3%.

Acknowledgement

This study was supported by the Natural Science Foundation of China (Grant No. 31470715) and (Grant No.31470714). It was also supported by the Natural Science Foundation of Heilongjiang Province (Grant No. LC201409).

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