Scientific Research Publishing

Optics and Photonics Journal, 2022, 12, 101-106
https://www.scirp.org/journal/opj
ISSN Online: 2160-889X
ISSN Print: 2160-8881

Experiments on Nanosecond Optical Parametric Generation for 486.0 nm in BBO Crystal

Yaqi Wang[1,2], Tingting Lu[1*], Qihui Luo[1,2], Jian Ma[1], Xiaolei Zhu[1,2]

[1]Key Laboratory of Space Laser Communication and Detection Technology, Shanghai Institute of Optics and Fine Mechanics, Chinese Academy of Sciences, Shanghai, China
[2]Center of Materials Science and Optoelectronics Engineering, University of Chinese Academy of Sciences, Beijing, China
Email: *tingting_lu@siom.ac.cn

How to cite this paper: Wang, Y.Q., Lu, T.T., Luo, Q.H., Ma, J. and Zhu, X.L. (2022) Experiments on Nanosecond Optical Parametric Generation for 486.0 nm in BBO Crystal. *Optics and Photonics Journal*, **12**, 101-106.
https://doi.org/10.4236/opj.2022.125008

Received: March 11, 2022
Accepted: May 17, 2022
Published: May 20, 2022

Abstract

In this paper, an injection-seeded nanosecond optical parametric generation (OPG) using BBO crystal, which combines relatively low thresholds with a simple and compact configuration, was demonstrated. By seeding externally with distributed feedback (DFB) diode laser at 1313 nm wavelength, pumped by 355 nm laser pulse, the maximum blue laser output power of 1.36 W at a rate of 100 Hz and with linewidth less than 0.13 nm were obtained, and the maximum optical to optical conversion efficiency was to 21.2%.

Keywords

Narrow Linewidth, Injection Seeding, All-Solid-State Blue Laser

1. Introduction

In the last decades, the all-solid-state blue laser has been one of the most attractive research directions in the laser community due to its extensive application prospects in scientific research, industry, medical, military, and other fields. In some applications, such as spectroscopy, remote sensing, and nonlinear optics, high pulse energy with short duration, narrow linewidth, compact size and high efficiency is desired [1] [2] [3]. The general approaches of all-solid-state blue laser generation can be classified into methods involving wide band-gap-semiconductor blue laser techniques, frequency up-conversion techniques and nonlinear frequency conversion techniques. However, it is difficult for all-solid-state blue laser to realize all the above performance at the same time. Especially for nanosecond (ns) laser, to fulfill the requirements of high efficiency, narrow linewidth and stable high power output remain an ongoing challenge.

Optical parametric generators (OPGs), as an optical component converting the wavelength of different pulsed laser sources into a broad spectral range from ultraviolet UV to far IR, have been widely used in laser systems. The OPGs have versatile and unique advantages for stable, narrow linewidth laser operation, including the compact structure and excellent compatibility with other nonlinear optical devices [1]. Compared to optical parametric oscillators (OPOs), OPGs are especially preferred for external seeding by narrow linewidth light sources for two reasons [4] [5] [6]. Firstly, an OPO has to control the cavity length to match the frequency of the seeding laser, but an OPG has no cavity and there is no need to actively control the cavity length. Besides, without a cavity, the structure of the OPGs is much more compact than the OPOs. Secondly, OPGs can operate in a single-pass fashion, which can avoid the feedback from the OPG system back toward the external seeding laser system. Operating in a single-pass fashion is important for single longitudinal mode (SLM) lasers, because even a little amount of feedback action can disturb SLM operation, and under certain circumstances can even damage the gain material. The latter is particularly important when using diode lasers as seeding [6]. Thus, the solid-state-blue-laser based on OPG was proposed to realize narrow linewidth laser output.

Over the past several years, there has been tremendous progress in nonlinear optical materials. Among them, the nonlinear crystal β-barium borate (β-BBO) is currently receiving much attention as a material for widely tunable optical parametric amplifiers (OPOs), OPAs and OPGs because of its broad transparent spectral range (from 0.19 to 3.5 μm), high damage threshold for nanosecond lasers and high effective nonlinearity, which is four times larger than that of potassium dihydrogen phosphate (KDP) [1] [2] [3] [4] [7] [8] [9]. In 1999, Sheng W *et al.* reported an injection-seeded nanosecond BBO-OPG/OPA pumped by 355 nm with the signal output tunable from 435 to 630 nm, where its total maximum energy conversion efficiency was 37% when the pump pulse energy was ~120 mJ, and the narrowest linewidth was ~0.2 nm at the wavelength of 435 nm [1]. Later, Dongqing P *et al.* reported a theoretical treatment of femtosecond parametric interaction process and investigated the pulse characteristics of OPG in BBO crystal [10].

This paper reports a 0.13 nm-linewidth, watt-level, nanosecond, external seeded OPG of SLM operation at a repetition rate of 100 Hz. The maximum output power of 1.36 W and conversion efficiency of 21% blue laser was obtained by a simple, compact BBO-OPG configuration.

2. Experimental Setup

The schematic diagram of the nanosecond OPG is shown in **Figure 1**. The laser system consists of three components, a homemade 355 nm pump laser, a diode laser injection-seeded system and a BBO-OPG unit.

Pump laser pulses were provided by the third harmonic output from a 1064 nm pulsed Nd: YAG laser. The laser delivered pulses at 355 nm of 12 ns pulse

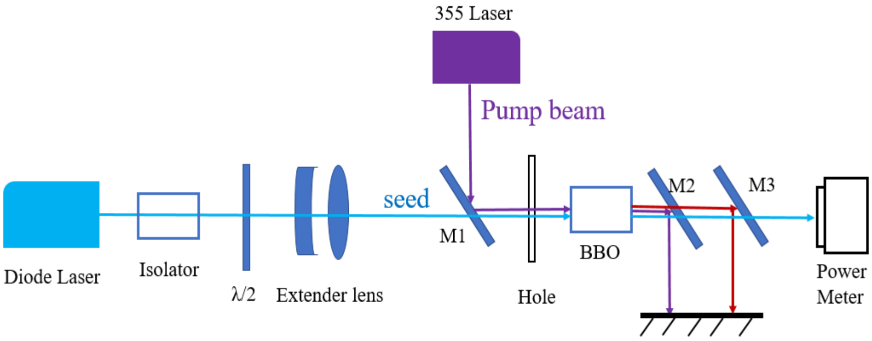

Figure 1. Schematic diagram of the experimental setup.

width, with 100 Hz of pulse repetition rates, as **Figure 2** shown. The laser beam was circular, approximately 6 mm in diameter, and had a smooth pulse temporal profile.

The injection-seeded system consists of a diode laser, an isolator, a half-wave plate and a pair of extender lenses. The seeding laser was a single longitudinal mode (SLM) CW 1313.5 nm distributed feedback (DFB) diode laser with a polarization-maintaining fiber. The isolator was aimed at protecting the diode laser from the laser radiation injury of the light path reflection. The half-wave plate was used to rotate the state of polarization of the seeder beam. And the extender lens was used to realize the beam expanding to match the size of the pump beam.

As **Figure 1** shows, our OPG unit mainly consists of a type-I phase matching BBO crystal with dimensions of 12 mm × 12 mm × 20 mm, cut at $\theta = 29.6^\circ$ and $\varphi = 90^\circ$. The plane mirror M1 was 45˚ high-reflection coated at 355 nm and anti-reflection coated at 486 nm, the plane mirror M2 was 45˚ high-reflection coated at 355 nm and anti-reflection coated at 486 nm and 1313 nm, while the plane mirror M3 was 45˚ high-reflection coated at 1313 nm and anti-reflection coated at 486 nm.

In the experiments, we carried out tests to characterize an external seeded OPG's parametric threshold, linewidth and efficiency. The diameter of the hole was chosen as 3 mm so that the most energy of the pump beam coincided with the seeding laser beam. Linewidth and signal power were tested separately under the same pump power. The signal and idler generated in the OPG stage passed through a pump reflecting dielectric mirror, and were then through an idler reflecting dielectric mirror, where there was only signal output of the OPG. **Table 1** lists the OPG output parametric thresholds, linewidth and conversion efficiencies at different pump powers.

3. Result and Discussion

The linewidth of the OPG output was measured by a Yokogawa AQ6373B optical spectrum analyzer, whose spectral resolution is 0.02 nm. **Figure 3** shows the spectrum of the output signal laser, of which the full width at half maximum (FWHM) was found to be 0.13 ± 0.02 nm, and the central wavelength was

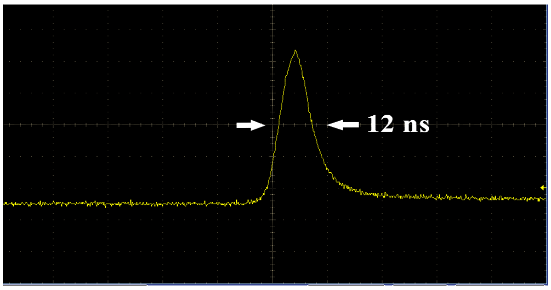

Figure 2. Pulse temporal profile of the 355 nm laser.

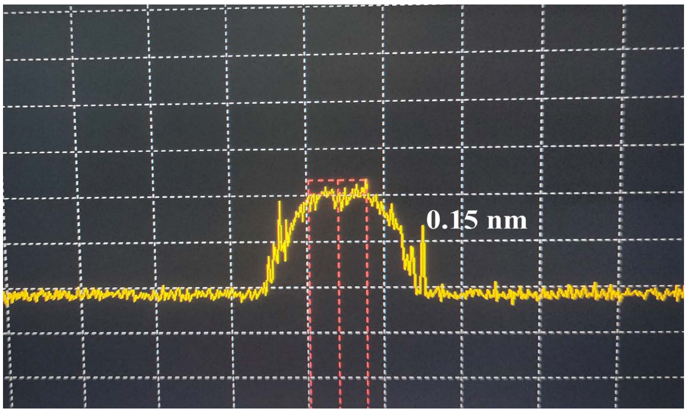

Figure 3. Spectrum of the OPG output under the pump power of 6.25 W.

Table 1. 1313.5 nm DFB laser diode seeded OPG characteristics.

Pump Power	OPG Characteristics[a]		
	Output power	Conversion efficiency	Linewidth
4.00 W	0.10 W	2.5%	0.11 nm
4.95 W	0.48 W	9.7%	0.13 nm
5.60 W	0.79 W	14.1%	0.15 nm
6.25 W	1.36 W	21.2%	0.15 nm

a. The parametric threshold was ~3.8 W, and the center wavelength of the output was ~486.00 nm.

around 486.0 nm. In the experiments, the narrowest linewidth was less than 0.11 nm analyzed under 4 W pump power, and the maximum linewidth was around 0.15 nm. With the increase of the pump pulse power, the linewidth of the OPG output was slightly increasing. While the pump power was increased to 5.6 W, the linewidth remained nearly constant.

Figure 4 shows the output characteristics when changing the pump power input. It can be seen that for the external 1313.5 nm-wavelength-laser seeded OPG, the output power and optical to optical conversion efficiency increased with the increase of the pump power. The maximum out power was 1.36 W when the pump power increased to 6.25 W, with the optical to optical conversion efficiency was to 21.2%.

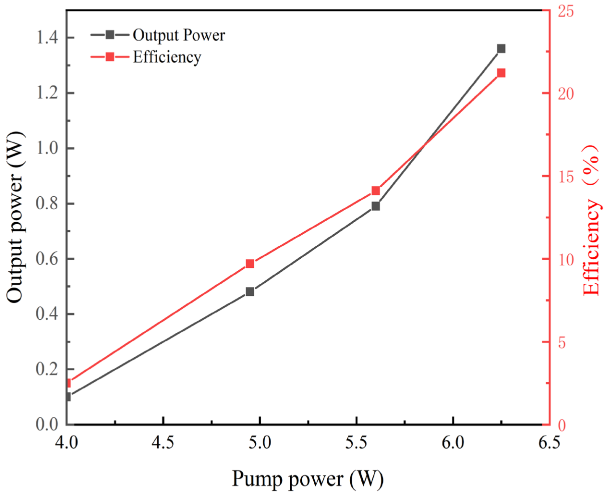

Figure 4. Output power and conversion efficiency of OPG.

4. Conclusion

We have demonstrated a narrow linewidth, low threshold and good conversion efficiency ns-OPG based on type I phase matching in BBO, outputting blue laser at the wavelength of 486.0 nm. The pump pulse was provided by the third harmonic 355 nm output from a pulsed Nd: YAG laser and the seeding source is an SLM CW DFB diode laser. Conversion efficiencies of approximately 21% are achievable, with a linewidth of ~0.13 nm and a threshold of ~3.8 W. Without a cavity of which optical properties must be actively controlled to match the injected radiation field (like in the cavity of OPO), the nonlinear optical device would be much more compact and simpler. Such laser sources would find wide applications in a variety of laboratory and diagnostic applications.

Acknowledgements

This work is supported by the Natural Science Foundation of Shanghai (No. 19YF1453600), the Key Task Project in Scientific and Technological Research on Social Development of Shanghai (No. 20dz1206502), the Marine S&T Fund of Shandong Province for Pilot National Laboratory for Marine Science and Technology (Qingdao) (No. 2018SDKJ0102), the Strategic Priority Research Program of the Chinese Academy of Sciences (No. XDA22000000), and the Major Program of the National Natural Science Foundation of China (No. 61991453).

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

References

[1] Wu, S., Kapinus, V.A. and Blake, G.A. (1999) A Nanosecond Optical Parametric Generator/Amplifier Seeded by an External Cavity Diode Laser. *Optics Communications*, **159**, 74-79. https://doi.org/10.1016/S0030-4018(98)00609-9

[2] Zhang, R.B., Pang, D.Q. and Wang, Q.Y. (2002) A Comparative Study of MR Imaging Profile of Titanium Pedicle Screws. *Applied Optics*, **41**, 1108-1112. https://doi.org/10.1364/AO.41.001108

[3] Rao, C.S., Kundu, S. and Ray, A.K. (2018) High Repetition Rate Nanosecond Optical Parametric Oscillator Pumped by the Third Harmonic of a DPSSL. *Applied Physics B*, **124**, 163. https://doi.org/10.1007/s00340-018-7035-5

[4] Joosen, W., Bakker, H.J., Noordam, L.D. and Muller, H.G. (1991) Parametric Generation in 8-Barium Borate of Intense Femtosecond Pulses near 800 nm. *Optical Society of America*, **8**, 2087-2093. https://doi.org/10.1364/JOSAB.8.002087

[5] Zhang, J.Y., Huang, J.Y., Shen, Y.R. and Chen, C. (1993) Optical Parametric Generation and Amplification in Barium Borate and Lithium Triborate Crystals. *Optical Society of America*, **10**, 1758-1764. https://doi.org/10.1364/JOSAB.10.001758

[6] Votava, O., Fair, J.R., Plusquellic, D.F., Riedle, E. and Nesbitt, D.J. (1997) Sub-Doppler Spectroscopy with a Narrow Linewidth Pulsed Optical Parametric Oscillator: Hyperfine Structure in the PF Radical. *Chemical Physics Letters*, **107**, 8854-8865.

[7] Bosenberg, W., Pelouch, W. and Tang, C.L. (1989) High-Efficiency and Narrow-Linewidth Operation of a Two-Crystal BaB_2O_4 Optical Parametric Oscillator. *Applied Physics Letters*, **55**, 1952-1954. https://doi.org/10.1063/1.102334

[8] Bapna, R.C., Rao, C.S. and Dasgupta, K. (2008) Low-Threshold Operation of a 355-nm Pumped Nanosecond β-BaB_2O_4 Optical Parametric Oscillator. *Optics & Laser Technology*, **40**, 832-837. https://doi.org/10.1016/j.optlastec.2007.11.009

[9] Wei, J.X., Chaitanya Kumar, S. and Ebrahim-Zadeh, M. (2021) Broadly Tunable, Intracavity Injection-Seeded, Hybrid Optical Parametric Oscillator. *Optics Letters*, **46**, 4502-4505. https://doi.org/10.1364/OL.434173

[10] Pang, D.Q., Zhang, R.B., Sun, J.H. and Wang, Q.Y. (2001) Theoretical Analysis of Noncollinear Phase-Matched Optical Parametric Generation in BBO Crystal. *Optics & Laser Technology*, **33**, 249-254. https://doi.org/10.1016/S0030-3992(01)00033-0