

Article

Growth of High-Quality CLBO Crystals for High-Power 266 nm DUV Laser

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Abstract

In this work, LiF was introduced as a flux additive to overcome the high viscosity challenge of the self-flux system, which successfully grew a large-scale cesium lithium borate (CLBO) single crystal with dimensions of $136 \times 132 \times 68 \text{ mm}^3$ and a weight of 1275 g via the top-seeded solution growth (TSSG) method. The as-grown crystal showed an optical transmittance of over 90% in the spectral range of 230–1880 nm and an extremely low absorption coefficient of 2.8 ppm/cm at 1064 nm. Notably, under 120 W pumping at a high repetition rate of 2 MHz, the fabricated CLBO optical element achieved a record-high 266 nm output power of 26.1 W with an optical conversion efficiency of 21.75%. Moreover, the laser system maintained stable continuous operation at >23 W for over 120 h.

Keywords: CLBO; deep-ultraviolet laser; 266 nm

1. Introduction

The 266 nm deep-ultraviolet (DUV) light, thanks to its short wavelength, high photon energy, and low thermal effect, plays an indispensable role in precision manufacturing and scientific research fields such as semiconductor dicing, chip fabrication, and high-density optical storage [1–3]. The generation of 266 nm light relies mainly on solid-state lasers. In the solid-state laser system, near-infrared light passes through several nonlinear crystals and then achieves frequency conversion to produce a 266 nm output. It has become the dominant approach because of its long lifetime, low operating cost, and good beam quality. In recent years, with the rapid expansion of 266 nm DUV laser applications, there has been an increasing demand for higher output power.

Significant progress has been made in this direction. For example, a home-built Nd: YVO₄ laser delivered a stable 266 nm output of 11 W, with an RMS fluctuation below 0.96% over 8 h. In this system, the pump beam spot was enlarged to suppress the thermal effects caused by two-photon absorption in the β -BaB₂O₄ (BBO) crystal [4]. In another work, using a 70 W, 100 kHz Nd: YVO₄ laser and BBO crystal, a 266 nm output of 10.6 W was achieved, with a conversion efficiency of 15.3% [5]. Internationally, CsLiC₆O₁₀ (CLBO)-based systems have reached over 26 W at megahertz repetition rates, and stable 20 W operation for 10,000 h has been demonstrated, with a maximum average power of 53 W [6]. These advances in high-power, long-term stable 266 nm lasers would not be possible without suitable nonlinear optical (NLO) crystals. However, under high-power operation, thermal effects in the crystal become a serious problem. The selection and growth quality



Academic Editor: Umberto Prisco

Received: 9 July 2026

Revised: 29 July 2026

Accepted: 31 July 2026

Published: 3 August 2026

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of nonlinear crystals therefore play a key role in further scaling the output power [7–9]. As described in the laser applications above, borate crystals are widely employed in solid-state lasers for high-power 266 DUV generation because of their large optical nonlinear and high transparency in the ultraviolet (UV) range, such as β -BaB₂O₄ (BBO) [10], CLBO [11], KBe₂BO₃F₂ (KBBF) [12], and NH₄B₄O₆F (ABF) [13]. Among these available candidates, CLBO stands out as an ideal material for 266 nm laser generation, owing to its broad transmission range, large nonlinear coefficient, high damage threshold, and suitability for high average power operation [11,14,15]. However, the growth of large-size and high-quality CLBO crystals remains challenging. In the self-flux growth system, the (B₃O₇)^{5−} rings originally present in the crystal transform into rings as the temperature rises [16]. These ring units no longer break apart but instead connect into larger ring-shaped structures. Then, these larger rings cross-link with each other, making it hard to further reduce the viscosity of the melt by rising temperature. The high viscosity at the growth temperature of CLBO crystal makes it difficult to improve melt flow and seriously slow down mass and heat transfer during crystal growth. For this reason, defects such as cracking, cloudiness, bubbles, and twinned crystals often appear. It is difficult to obtain a crystal with good integrity and high optical quality for device fabrication.

Thus, efforts in solving the problem of high melt viscosity in the self-flux growth system are important. Currently, there are lots of researchers that have been working on the problem, which mainly focuses on growth temperature control schemes and the optimization of flux systems. As for temperature control schemes, researchers have also made considerable progress. One effective approach is to optimize the seed-holder design to reduce the crystal cooling rate. This allows the growth of defect-free CLBO crystals as large as 80 × 80 × 60 mm³ [17]. Another important advance is the use of precision multi-zone furnaces. By simulating and optimizing the temperature field, high-quality CLBO single crystals measuring 120 × 112 × 62 mm³ have been successfully grown, with over 90% transmittance in the 210–1800 nm range [18]. In terms of the flux systems, NaF is a typical alkali metal fluoride and is often used as a flux additive. At a high temperature, the F[−] ions can break up the boron–oxygen bonds, which greatly reduces the viscosity of the melt, ultimately yielding 54 × 51 × 32 mm³ CLBO crystals with superior quality and stability compared to those grown with conventional fluxes [19]. MoO₃ is another effective additive. It also reduces the viscosity by breaking up the boron–oxygen network. With a certain proportion of MoO₃ added, a CLBO crystal measuring 61 × 59 × 35 mm³ and weighing 125 g has been successfully grown [20].

However, NaF introduces extra Na⁺ ions into the melt, which may affect the crystal quality [21]. MoO₃, on the other hand, can leave Mo-related impurities. LiF, also an alkali metal fluoride, has not yet been studied as an additive for CLBO growth. At present, the crystal quality from existing methods is still not good enough for demanding applications, and domestic research on CLBO for high-power, high-repetition-rate 266 nm lasers remains limited. In this work, LiF was selected as an additive to address the high viscosity issue of the self-flux system for the growth of CLBO crystals. A high-quality CLBO crystal with dimensions of 136 × 132 × 68 mm³ and weight of 1275 g was grown using the top-seeded solution growth method. After cutting and polishing, the CLBO crystal was characterized by transmittance, weak absorption, and surface figure tests. Under 120 W 532 nm pumping, the polished CLBO element achieved 26.1 W 266 nm output with 21.75% conversion efficiency. In terms of power stability, a continuous laser output of no less than 23 W was maintained over 120 h, with a decay ratio of approximately 10%. This study verifies the feasibility of growing large-size, high-quality CLBO crystals via LiF flux and their application in high-power 266 nm lasers.

2. Materials and Methods

2.1. Crystal Growth Process

In this experiment, the CLBO crystal was grown via the TSSG method. The specific raw material compositions and operational procedures are detailed as follows. High-purity Cs_2CO_3 (99.99 wt.%), Li_2CO_3 (99.99 wt.%), LiF (99.99 wt.%), and H_3BO_3 (99.99 wt.%) were used as flux raw materials. The raw materials were weighed and mixed at a molar ratio of $\text{Cs}_2\text{CO}_3:\text{Li}_2\text{CO}_3:\text{H}_3\text{BO}_3:\text{LiF} = 1:1:12:0.2$ and then melted in a platinum crucible using a high-temperature muffle furnace. After cooling, the crucible containing the solidified flux was transferred to a crystal growth furnace and slowly reheated until the solution became transparent, followed by uniform stirring with a platinum stirrer. The saturation temperature of the flux system was accurately determined. A c-oriented seed crystal was then introduced to touch the melt surface at the saturation temperature. During the growth process, the seed crystal was rotated at a constant speed of 50~60 rpm, and the melt temperature decreased at a controlled rate of $0.05\text{ }^\circ\text{C}\sim 0.1\text{ }^\circ\text{C}/\text{day}$. After a growth period of 30 days, the crystal was slowly lifted above the melt and cooled to room temperature at $5\text{ }^\circ\text{C}\sim 15\text{ }^\circ\text{C}/\text{h}$, which effectively released internal thermal stresses and prevented cracking. Finally, a transparent CLBO crystal with dimensions of $136 \times 132 \times 68\text{ mm}^3$ and a weight of 1275 g was successfully obtained. As shown in Figure 1, the as-grown crystal exhibits a regular habit, free from cracks, inclusions, or other macroscopic defects.

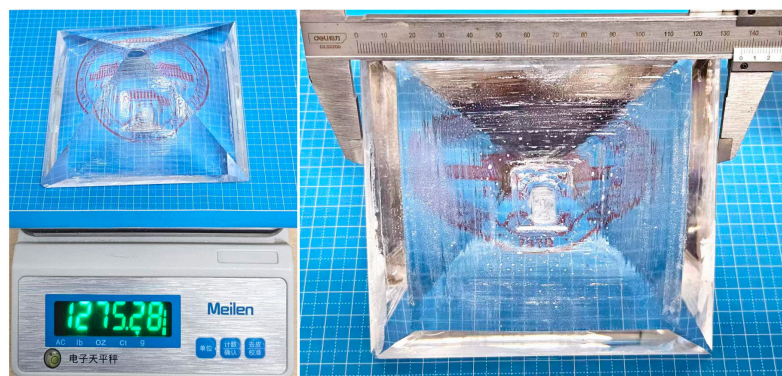


Figure 1. Photographs of CLBO crystal grown by TSSG method (The Chinese characters shown in the figure denote the name of the electronic balance).

2.2. Characterization Techniques

The viscosity of high-temperature flux was measured by a DVII + Pro viscometer (Brookfield Co., Middleboro, MA, USA). The control temperature was raised to $1000\text{ }^\circ\text{C}$ at $5\text{ }^\circ\text{C}/\text{min}$, held for measurement, and then cooled down at $2\text{ }^\circ\text{C}/\text{min}$. During cooling, viscosity was measured at staged intervals ($200\text{ }^\circ\text{C}$ in the early stage, $100\text{ }^\circ\text{C}$ later). Measurements continued until viscosity increased exponentially. Each interval was held for 1 h. The measured furnace temperature was $70\text{--}80\text{ }^\circ\text{C}$ below the control temperature.

X-ray diffraction (XRD) analysis was conducted on the powdered crystal samples (Model: SmartLab 9 kW, Rigaku Corporation, Tokyo, Japan) to confirm the crystal phase.

Energy dispersive X-ray spectroscopy (EDS/EDX) was utilized to examine the elemental distribution and verify the stoichiometric ratio of Cs, B, and O (Model: Verios 460 L, Thermo Fisher Scientific Inc., Waltham, MA, USA).

Optical transmittance of the polished crystals was recorded using a UV-VIS-NIR spectrophotometer (Model: UH4150, Hitachi High-Tech Science Corporation, Tokyo, Japan).

The weak absorption coefficient was tested via a photothermal weak absorption spectrometer (Stanford Photo-Thermal Solutions, Palaiseau, France), with a sensitivity of $0.1\text{ ppm}/\text{cm}$ under 1064 nm pump laser irradiation at a power of 2.5 W .

The surface figure and wavefront distortion were characterized using a Verifire 6 interferometer (Zygo Corporation, Middlefield, CT, USA) with a working wavelength of 632.8 nm.

A CLBO crystal device was integrated into a picosecond 532 nm DUV solid-state laser system for fourth harmonic generation. The conversion efficiency, power output, and long-term stability were systematically characterized. Measurement temperature was kept at 150 °C for measurement stability. The 266 nm laser power was measured using a power meter (Model: FL400-A-BB-50, Jerusalem, Israel).

Data processing and graph plotting were performed using OriginPro 2026 software (OriginLab Corporation, Northampton, MA, USA).

3. Results

3.1. Flux Viscosity and Growth Conditions

The viscosity of the self-flux system (i.e., Cs:Li:B = 1:1:6) for growing CLBO crystals usually has a high viscosity, which is often beyond 1000 cP at a typical growth temperature. This high melt viscosity arises from the three-dimensional cross-linked B–O network. As reported in previous studies, F^- ions reduce melt viscosity by depolymerizing B–O structural units. Thus, we introduced LiF to further lower the viscosity and obtained an optimized composition (i.e., Cs:Li:B:F = 1:1:6:0.1) on the basis of the base composition. As shown in Figure 2, compared with the self-flux system, the viscosity of the LiF-doped melt dropped sharply from 1103.6 cP to 544.5 cP at 844 °C. This significant drop in melt viscosity can be attributed to the addition of F^- ions. Furthermore, the co-introduced Li^+ avoids the introduction of extraneous impurity ions, which is favorable for the growth of high-purity crystals.

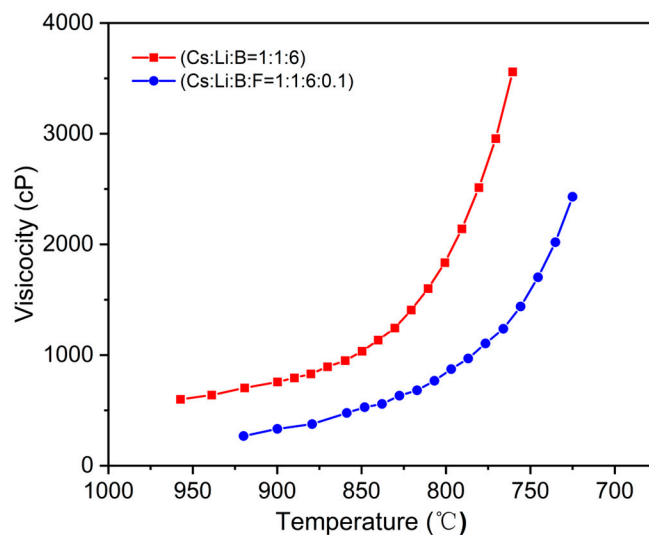


Figure 2. Temperature–viscosity curves of partial flux systems.

3.2. Structural Characterization

The single crystal X-ray diffraction measurement was carried out for the grown crystal. The grown CLBO crystal was crushed and subjected to powder X-ray diffraction measurement. The sample was scanned over the range of 10–80° at a scan rate of 20°/s. As shown in Figure 3, all characteristic diffraction peaks of crystals synthesized via the LiF system and self-flux method match well with the standard XRD profile (PDF#82-1892). These results verify that LiF incorporation has no influence on the fundamental crystal structure of CLBO, demonstrating that the grown crystals are high-purity CLBO.

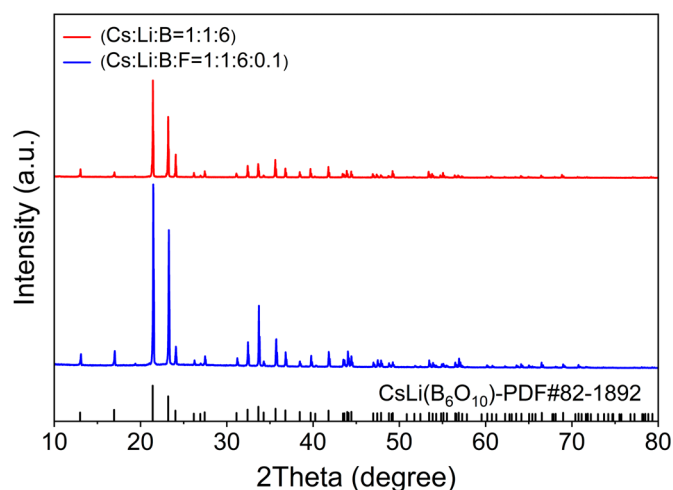


Figure 3. Powder X-ray diffraction pattern of undoped and LiF-doped CLBO crystals.

EDX analysis was performed on the polished crystal surface (Figure 4a), and the results are shown in Figure 4b. The EDX spectrum shows no impurity peaks. Only the characteristic peaks of B, O, and Cs are observed. It should be noted that light elements such as Li, B, and O are difficult to measure accurately by EDX, because their low-energy characteristic X-rays are easily absorbed and have a low fluorescence yield. This is especially true for Li, whose characteristic X-rays are completely outside the detection range of the EDX system. For this reason, it is reasonable that the quantitative analysis shows some deviation from the ideal stoichiometric ratio of Cs:B:O = 1:6:10.

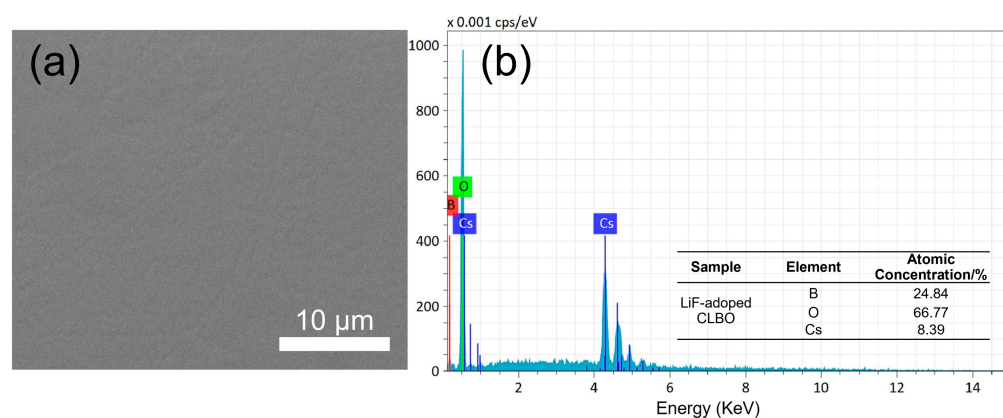


Figure 4. EDX analysis of the polished surface of LiF-doped CLBO crystal. (a) SEM image of the EDX testing area; (b) EDX spectrum.

3.3. Optical Quality of the Grown Crystal

CLBO crystals grown using the LiF doping flux system were cut along the phase-matching direction ($\varphi = 45^\circ$, $\theta = 62^\circ$) into $10 \times 10 \times 3$ mm³ fourth-harmonic generation elements and then polished for UV-Vis-IR transmittance. The transmittance curve of the component is shown in Figure 5, with an inset photograph of the polished optical element. The crystal shows an average transmittance exceeding 90% over the wavelength range of 230–1880 nm. This transmittance satisfies the quality demands for high-power ultraviolet frequency doubling output and is beneficial for achieving efficient frequency doubling [15].

Weak absorption is also an important optical property of crystal. It directly shows light absorption ability under specific wavelengths. Figure 6 gives a weak absorption curve measured along the [001] direction of the optical component. The two absorption peaks on the curve are attributed to the weak absorption of the two end faces and the region between

them corresponds to the weak bulk absorption. As the curve shows, the measured weak absorption is only 2.8 ppm/cm at 1064 nm. Compared with values reported in the existing literature, such as 40 ppm/cm [22] and 50 ppm/cm [18,20], the value obtained in this work is much lower. This further confirms the low impurity content of the crystal.

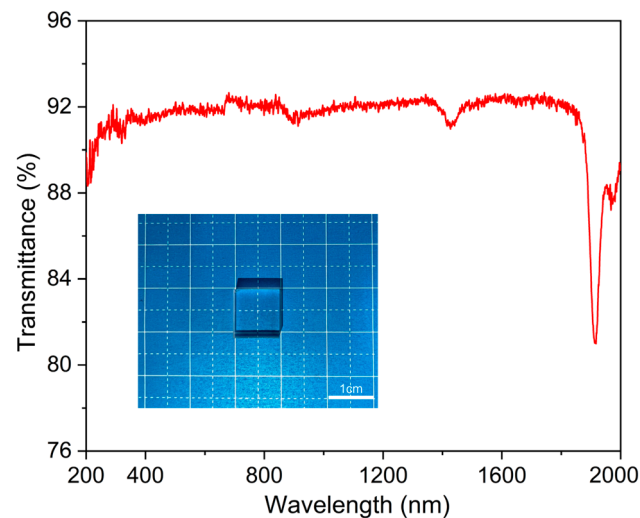


Figure 5. UV-Vis-NIR transmittance curves of the polished CLBO crystal ($10 \times 10 \times 3 \text{ mm}^3$), with an embedded photograph of the crystal.

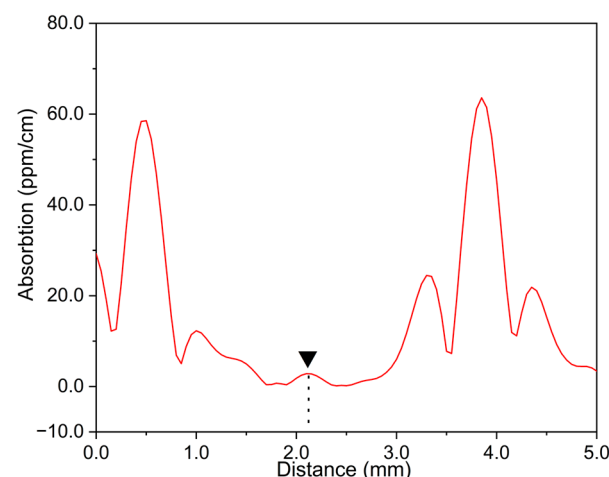


Figure 6. [001] Orientation weak absorption spectra. The black triangle denotes the crystal center, corresponding to the valley position with the minimum bulk weak absorption.

The experimental results of surface figure and wavefront distortion of the CLBO crystals are shown in Figure 7 with crystal sample dimensions of $12 \times 12 \times 15 \text{ mm}^3$. For both weak absorption and surface figure, the tested surfaces are the ones that correspond to the phase-matching direction ($\varphi = 45^\circ$, $\theta = 62^\circ$). Figure 7a shows the surface figure results, with a PV value is 0.105λ and an RMS value of 0.018λ . These results indicate not only that the peak-to-valley difference is very small, but also that the crystal is suitable for high-precision laser applications [23]. Figure 7b shows the wavefront distortion pattern of the crystal with a PV value is 0.137λ and an RMS value of 0.028λ . This pattern reflects how the light beam changes after passing through the crystal, mainly due to the crystal's own refractive index. The measured wavefront has a total RMS of 0.028λ and shows a clear saddle-shaped astigmatism. According to classic optical testing theory [24], this smooth, low-order pattern fits well with a second-order Zernike polynomial, indicating that there are no large defects such as inclusions or sudden refractive index changes inside the crystal.

This confirms the high optical uniformity of the crystal. The measured pattern matches well with the wavefront fitted by a second-order Zernike polynomial. This means the distortion is mostly low-order astigmatism. There are no local color shifts caused by large defects. This further confirms the good quality of the crystal.

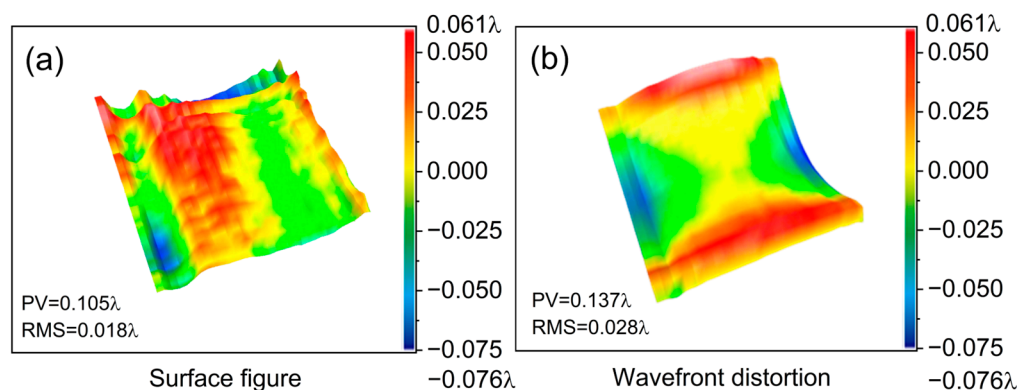


Figure 7. (a) Surface figure of CLBO crystal. (b) Wavefront distortion patterns of crystal devices.

3.4. 266 nm Deep-Ultraviolet Laser Performance

After a series of optical tests, the as-grown high-quality CLBO optical element with dimensions of $12 \times 12 \times 15 \text{ mm}^3$ ($\varphi = 45^\circ$, $\theta = 62^\circ$) was finally applied to the deep-ultraviolet solid-state laser system shown in Figure 8. In this system, the fundamental 1064 nm laser is frequency-doubled by an LBO crystal to generate a 532 nm green beam, which is then converted by a LiF-doped CLBO crystal into 266 nm ultraviolet output. The 266 nm laser power was characterized with a power meter.

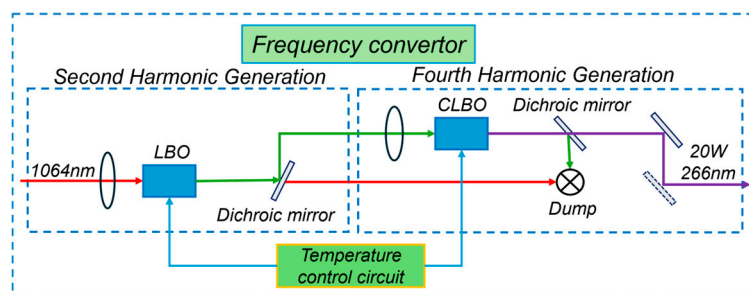


Figure 8. Schematic diagram of a picosecond solid-state laser for deep ultraviolet 266 nm output. Red, green and purple arrows denote the 1064 nm fundamental laser, 532 nm second-harmonic laser and 266 nm fourth-harmonic laser, respectively. Using the laser system, the dependence of the 266 nm output power on the fundamental laser power is illustrated in Figure 9, along with the corresponding conversion efficiency. During the single-pass experiment, the CLBO crystal was maintained at a constant temperature of 150°C in a temperature-controlled oven. The 532 nm pump laser had a repetition rate of 2 MHz, a pulse width of 9 ps, and a beam diameter of 3 mm incident on the crystal. As the 532 nm laser power increases, both the 266 nm output power and the conversion efficiency exhibit an overall positive correlation. At an input power of 120 W, the maximum output power reached 26.1 W, corresponding to an optical-to-optical conversion efficiency of 21.75% (calculated as the ratio of 266 nm output power to 532 nm input power). And the peak power density at the maximum power was $94.3 \text{ MW}/\text{cm}^2$.

For comparison, a recent investigation using commercialized CLBO crystals achieved a 14 W 266 nm laser output under a 100 kHz repetition rate [25]. In contrast, our experiment operated at a much higher repetition rate of 2 MHz. Such a high repetition rate usually causes more thermal buildup and lowers nonlinear conversion efficiency. Even so, we achieved a superior output power of 26.1 W. This distinct performance disparity verifies

that the high-quality CLBO single crystal grown in this work has great potential for high-repetition-rate deep ultraviolet (DUV) laser devices.

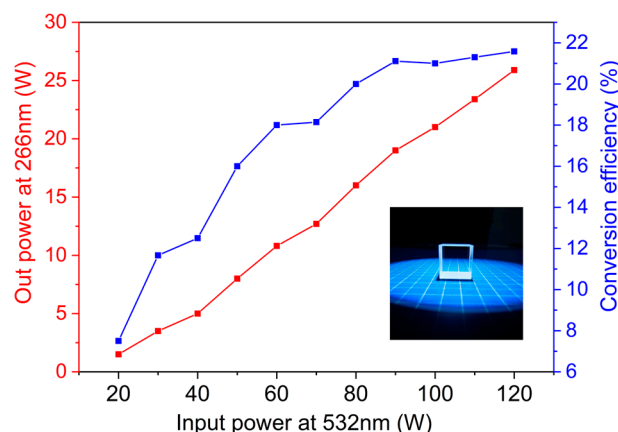


Figure 9. Relationship curves of fundamental power, 266 nm output power, and conversion efficiency (inset: photograph of a power device measuring 15 mm in length).

We further evaluated the long-term output power stability of the as-grown CLBO crystal, with the results presented in Figure 10. During the first 24 h, the laser output decreased from 26 W to 23 W. This initial power decay is mainly attributed to the slow temperature stabilization inside the crystal. The heat buildup slightly shifts the optimum condition for frequency conversion, leading to a small drop in output. After the crystal temperature stabilized, the output power stayed above 23 W for a continuous test of 120 h. Such long-term high-power stability data have rarely been reported in the domestic literature. Unfortunately, the test could not be extended further because of the limitations of our equipment.

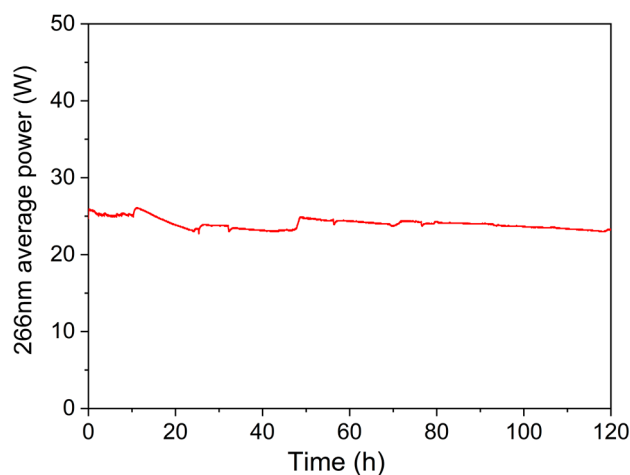


Figure 10. Curve of 266 nm average output power as a function of time.

Despite the improved output power and stability demonstrated above, the average conversion efficiency remains relatively low compared to other studies [26]. This can be attributed to several factors: (i) heat accumulation under high-repetition-rate operation at 2 MHz [27,28]; (ii) the optical quality of the home-grown crystal is still under improvement; (iii) the phase-matching condition for second harmonic generation is not yet fully optimized. These results show that LiF-doped CLBO crystals are well suited for high-repetition-rate, high-power 266 nm DUV laser applications. With further improvements in crystal quality and phase-matching conditions, the conversion efficiency can be pushed higher.

4. Conclusions

In summary, LiF was selected as an efficient growth additive to reduce the melt viscosity of the self-flux system for CLBO crystal growth. High-quality CLBO single crystals with a size of $136 \times 132 \times 68 \text{ mm}^3$ and weight of 1275 g were successfully grown via the TSSG method. XRD analysis confirmed that the grown crystal retains the standard CLBO structure, and EDX mapping verified the elemental composition. Optical measurements demonstrate that the fabricated CLBO crystal achieves a transmittance of over 90% in the spectral range of 230–1880 nm and a low absorption coefficient of 2.8 ppm/cm at 1064 nm. The surface figure shows a PV value of 0.105λ and an RMS of 0.0108λ , indicating good optical quality. In high-power-output experiments, a CLBO element ($12 \times 12 \times 15 \text{ mm}^3$, $\varphi = 45^\circ$, $\theta = 62^\circ$) was used in a 532 nm picosecond pump system. At 120 W pump power and 2 MHz repetition rate, a 266 nm output of 26.1 W was achieved, with a conversion efficiency of 21.75%. The laser system can operate continuously and stably for 120 h.

Author Contributions: Conceptualization, L.Y.; writing—original draft preparation, J.W.; review and editing, L.Y., G.H., Z.H. and J.W.; supervision, G.H. and Z.H. All authors have read and agreed to the published version of the manuscript.

Funding: This work was supported by the National Key Research and Development Program of China (No. 2023YFB3610602), the National Natural Science Foundation of China (NSFC) (No. 12304455), and the Major Special Project of National Key Laboratory in Tianjin (25ZXZSSS00470).

Data Availability Statement: The original contributions presented in this study are included in the article. Further inquiries can be directed to the corresponding authors.

Acknowledgments: This work was prepared without the use of artificial intelligence (AI) tools for content generation. All scientific ideas, analyses, and interpretations presented in this review are entirely the authors' original contributions.

Conflicts of Interest: The authors declare no conflicts of interest.

References

1. Takeda, M.; Furuki, M.; Yamatsu, H.; Kashiwagi, T.; Aki, Y.; Suzuki, A.; Kondo, K.; Oka, M.; Kubota, S. Deep UV Mastering Using an All-Solid-State 266 nm Laser for an over 20 GBytes/Layer Capacity Disk. *Jpn. J. Appl. Phys.* **1999**, *38*, 1837–1838. [\[CrossRef\]](#)
2. Ahmadivand, A.; Gerislioglu, B. Deep- and Vacuum-Ultraviolet Metaphotonic Light Sources. *Mater. Today* **2021**, *51*, 208–221. [\[CrossRef\]](#)
3. Aryal, A.; Kanaujia, P.K.; Surampudi, A.; Bower, D.M.; Hewagama, T.; Prasad, N.S.; Moore, W.B.; Gupta, M.C. A High Spatial and Depth Resolution Deep-UV 266 nm Wavelength Laser-Based Integrated LIBS, Fluorescence, and Raman System for Probing Lunar and Planetary Simulants and Geological Materials. *ACS Omega* **2025**, *10*, 40958–40967. [\[CrossRef\]](#) [\[PubMed\]](#)
4. Ou, Z.Y.; Xu, S.Z.; Liu, X.; Gao, Y.B.; Chen, J.Z.; He, X.Y.; Lu, H.T.; Wu, C.H.; Guo, C.Y.; Guo, L.; et al. All-solid-state high-power deep ultraviolet picosecond laser. *Acta Phys. Sin.* **2025**, *74*, 144204. [\[CrossRef\]](#)
5. Cui, Z.J.; Xu, J.Z.; Lu, C.X.; Shi, Y.Q.; Liu, W.F.; Sun, M.Y.; Liu, D.A.; Zhu, J.Q. High-power picosecond UV and deep-UV laser sources delivering powers of 30 W at 355 nm, 10 W at 266 nm, and 5 W at 213 nm. *Opt. Lett.* **2024**, *49*, 6497–6500. [\[CrossRef\]](#) [\[PubMed\]](#)
6. Yoshimura, M.; Takahashi, Y.; Murai, R.; Mori, Y.; Kohno, K.; Tanaka, H.; Shibuya, K.; Okada, G.; Nishimae, J. Development of Nonlinear Optical Crystals for Generation of Deep-Ultraviolet Light. *Rev. Laser Eng.* **2024**, *52*, 11. [\[CrossRef\]](#) [\[PubMed\]](#)
7. Kang, L.; Lin, Z. Deep-Ultraviolet Nonlinear Optical Crystals: Concept Development and Materials Discovery. *Light Sci. Appl.* **2022**, *11*, 201. [\[CrossRef\]](#) [\[PubMed\]](#)
8. Wang, H.; Mao, J.; Ye, S.; Wang, J. Research Progress of High-Power 266 nm All-Solid-State Single-Frequency CW Laser. *Infrared Laser Eng.* **2023**, *52*, 20220885-1–20220885-11.
9. Yan, Z.; Fan, J.; Pan, S.; Zhang, M. Recent Advances in Rational Structure Design for Nonlinear Optical Crystals: Leveraging Advantageous Templates. *Chem. Soc. Rev.* **2024**, *53*, 6568–6599. [\[CrossRef\]](#) [\[PubMed\]](#)
10. Fedorov, P.P.; Kokh, A.E.; Kononova, N.G. Barium Borate $\beta\text{-BaB}_2\text{O}_4$ as a Material for Nonlinear Optics. *ChemInform* **2003**, *34*, 741–763. [\[CrossRef\]](#)

11. Mori, Y.; Kuroda, I.; Nakajima, S.; Sasaki, T.; Nakai, S. New Nonlinear Optical Crystal: Cesium Lithium Borate. *Appl. Phys. Lett.* **1995**, *67*, 1818–1820. [[CrossRef](#)]
12. Mei, L.F.; He, C.Z.; Chen, C.T. Flux growth of $\text{KBe}_2\text{BO}_3\text{F}_2$. *J. Cryst. Growth* **1993**, *132*, 609–610. [[CrossRef](#)]
13. Zhang, F.F.; Chen, Z.L.; Cui, C.; Yang, Z.H.; Mutailipu, M.; Li, F.M.; Hou, X.L.; Long, X.F.; Pan, S.L. Vacuum ultraviolet second-harmonic generation in $\text{NH}_4\text{B}_4\text{O}_6\text{F}$ crystal. *Nature* **2026**, *650*, 97–101. [[CrossRef](#)] [[PubMed](#)]
14. Sasaki, T.; Mori, Y.; Yoshimura, M.; Yap, Y.K.; Kamimura, T.M. Recent Development of Nonlinear Optical Borate Crystals: Key Materials for Generation of Visible and UV Light. *Mater. Sci. Eng. R* **2000**, *30*, 1–54. [[CrossRef](#)]
15. Kumar, A. Borate Crystals for Nonlinear Optical and Laser Applications: A Review. *J. Chem.* **2013**, *2013*, 154862. [[CrossRef](#)]
16. Wang, J.; You, J.L.; Wang, Y.Y.; Zhang, G.C.; Wan, S.M.; Fu, P.Z.; Yin, S.T.; Liu, Q.; Wang, C.Y.; Liu, X.W. High Temperature Raman Spectroscopic Study on the Micro-structures of $\text{CsLiB}_6\text{O}_{10}$ Crystal and Its Melt. *J. Synth. Cryst.* **2013**, *42*, 397–401.
17. Sun, T.Q.; Wang, X.Q.; Shen, G.Q.; Wang, X.Q.; Shen, D.Z. Growth and Ultraviolet Frequency Doubling Properties of Cesium Lithium Borate (CLBO) Crystals. *J. Synth. Cryst.* **2004**, *33*, 181–184.
18. Shi, S.S.; Wang, G.Y.; Xiao, Y.B. Growth and Properties of CLBO Single Crystals. *J. Synth. Cryst.* **2023**, *52*, 2146–2150.
19. Yu, X.; Hu, Z.G. Flux Growth of $\text{CsLiB}_6\text{O}_{10}$ Crystals. *J. Cryst. Growth* **2010**, *312*, 2415–2418. [[CrossRef](#)]
20. Zhu, X.C.; Tu, H.; Zhao, Y.; Hu, Z.G. Growth of High Quality Al-Doped $\text{CsLiB}_6\text{O}_{10}$ Crystals Using $\text{Cs}_2\text{O-Li}_2\text{O-MoO}_3$ Fluxes. *Crystals* **2017**, *7*, 83. [[CrossRef](#)]
21. Kim, J.; Yoon, C.S.; Gallagher, H.G. The Effect of NaCl Melt-Additive on the Growth and Morphology of LiB_3O_5 (LBO) Crystals. *J. Cryst. Growth* **2001**, *222*, 760–766. [[CrossRef](#)]
22. Li, X.M.; Hu, Z.G.; Yue, Y.C.; Yu, X.S.; Lin, Z.S.; Zhang, G.C. Study on Optical Weak Absorption of Borate Crystals. *Opt. Mater.* **2013**, *35*, 2376–2381. [[CrossRef](#)]
23. Li, J.; Wang, F.; Fan, B. Measurement on Optical Plane Surface Based on ASTM Method. *Opt. Instrum.* **2015**, *37*, 4.
24. Mahajan, V.N. Zernike Polynomial and Wavefront Fitting. In *Optical Shop Testing*, 3rd ed.; Malacara, D., Ed.; Wiley: New York, NY, USA, 2007.
25. Yu, Y.H.; Zhang, Z.T.; Xuan, H.W. High-Efficiency, High-Power Deep Ultraviolet 266 nm Laser Based on Domestic Commercial CLBO Crystal. *Chin. J. Lasers* **2024**, *51*, 0701020.
26. Sekine, T.; Sakai, H.; Takeuchi, Y.; Hatano, Y.; Kawashima, T.; Kan, H.; Kawanaka, J.; Miyana, N.; Norimatsu, T. High Efficiency 12.5 J Second-Harmonic Generation from $\text{CsLiB}_6\text{O}_{10}$ Nonlinear Crystal by Diode-Pumped Nd:glass Laser. *Opt. Express* **2013**, *21*, 8393–8400. [[CrossRef](#)] [[PubMed](#)]
27. Yao, J.Q.; Xu, D.G. Analysis of Thermal Effects in High-Power Laser Frequency Doubling Process. *Chin. J. Quantum Electron.* **2005**, *22*, 508–513. [[CrossRef](#)]
28. Orii, Y.; Sawada, H.; Okuyama, D.; Yamagaki, M.; Izumi, H.; Shibuya, K.; Okada, G. High-Power Deep-Ultraviolet Picosecond Laser. *Rev. Laser Eng.* **2017**, *45*, 580. [[CrossRef](#)] [[PubMed](#)]

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