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High conversion efficiency and extra-cavity sum frequency 355nm UV laser output

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Abstract. Currently, the common method to obtain ultraviolet laser is an all-solid-state laser combined with nonlinear frequency conversion technology, which generates three, four or five harmonics outside or inside the resonator cavity through the frequency conversion of near-infrared light waves around 1.0μm. Ultraviolet light sources are mainly obtained in two bands of 355mm and 266nm. Ultraviolet laser is characterized by high photon energy, short wavelength, cold treatment and good focusing performance, be widely used in the fields of medicine and biology, industrial microprocessing, atomic/analytical spectroscopy and chemical dynamics, environmental detection and atmospheric detection. In this article, we put forward with two sum frequency crystals to obtain UV laser, based on the method of theoretical analysis and experiment validation, Nd:YAG crystal was used as a gain medium to generate 1064 nm laser, double frequency generated 532 nm green laser by KTP crystal, 1064 nm and 532 nm throughed two sum frequency crystals and frequency conversion outside the cavity. The High conversion efficiency and high peak power 355nm ultraviolet light output is realized.

1. Introduction

Ultraviolet laser is widely used in processing[1], detection[2] and biology[3] because of its advantages such as short wavelength, good focusing performance, high photon energy, small spot area, small diffraction effect and high resolution. At present, researches on all solid state ultraviolet lasers are mostly focused on obtaining high peak power ultraviolet laser output by using extra-cavity double frequency and triple frequency[4][5][6]. However, the traditional sum frequency technology often uses single sum frequency crystal for frequency conversion, but this method has some limitations in improving the output power and conversion efficiency of ultraviolet light. Therefore, this paper proposes a scheme of ultraviolet laser output by using dual sum frequency crystasl to sum frequency. Nd:YAG crystal is the gain medium. We compared several common double frequency crystals and sum frequency crystals, and finally chose KTP crystal as the double frequency crystal and LBO crystal as the sum frequency crystal. On the basis of theoretical analysis, experimental research was carried out, and finally 355nm ultraviolet light output was obtained. The conversion efficiency is obviously higher than that by single sum frequency crystal.

2. Experimental methods and results

In the experiment, we use the FieldMaster-GS energy meter produced by coherent company in the United States to measure the output energy of 1064nm fundamental light and analyze the influence of pump voltage with the output energy of 1064nm laser. Figure1 shows the experimental device. Where,1: the total reflective mirror of the resonator, 2: electro-optic q-switched crystal, 3: the aperture,

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4: the polarizer, 5: rectangular prism, 6: the output mirror of resonator, 7: 1064nm laser source, 8: rectangular prism, 9: the first-level amplified laser source, 10: double frequency crystal, 11: sum frequency crystal. Among them, devices 1, 7 and 6 constitute the 1064nm fundamental frequency optical resonator; devices 2 and 4 constitute the electro-optic Q modulation system; devices 5 and 8 make the 1064nm fundamental light turn 90 degrees, parallel to the original light path, into the first-level amplification laser source; devices 10 and 11 perform nonlinear frequency transformation outside the resonator cavity. Figure2 shows the relationship between 1064nm laser output energy and pump light source voltage. Figure3 shows the images of the quality of 1064nm fundamental light beam.

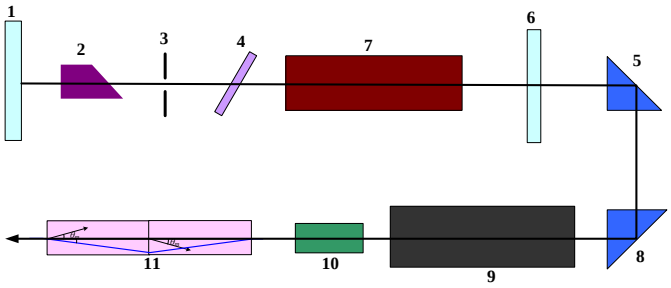


Figure1. The experimental device

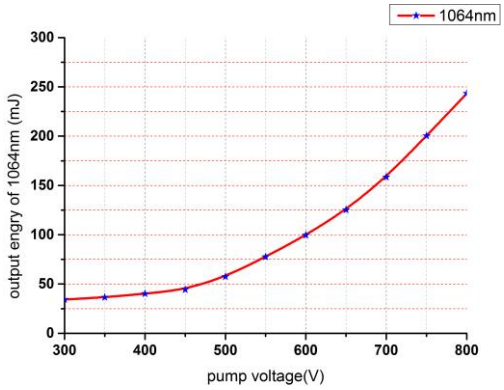


Figure 2. The relationship between 1064nm laser output energy and pump voltage.

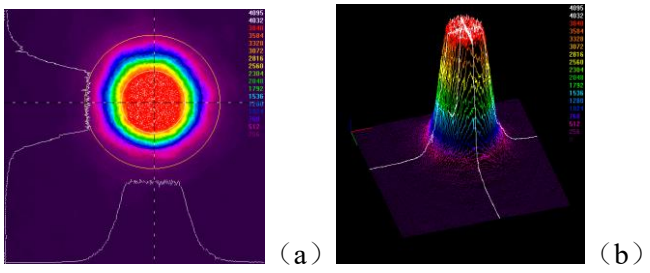


Figure3. The beam quality image of 1064nm fundamental light.(a)2D image, (b)3D image.

It can be seen from figure 2 that the laser energy at 1064nm increases with the pump voltage. When the power supply voltage increases to 800V, the fundamental frequency light energy at 1064nm can be as high as 243mJ. The pulse width of 1064nm fundamental light is only more than ten ns, which successfully compresses the pulse width of fundamental light, which is conducive to improving the conversion efficiency of doublle frequency and sum frequency.

In the double frequency experiment, the effect of the length of the double frequency crystal on the conversion efficiency is mainly considered, in which the aperture length and characteristic length need to be taken into comprehensive consideration[7], so as to achieve higher efficiency frequency conversion of the fundamental frequency light in the double frequency crystal. Finally, the KTP length was selected as 7mm, and the matching method was type II phase matching. As the energy of 1064nm fundamental frequency light injected into KTP crystal increases, the output energy of 532nm double frequency light also increases, as shown in Figure 4. finally, the output energy of 532nm is 145mJ. Figure 5 shows the beam quality image of double frequency light

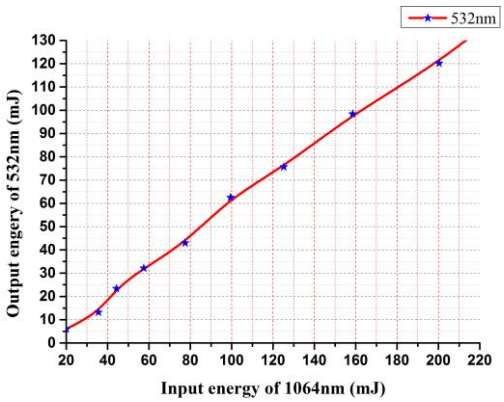


Figure 4. The relationship between the output energy of 532nm with the input energy of 1064nm

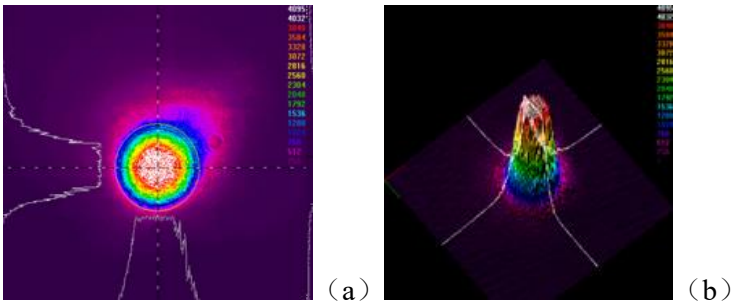


Figure 5. The beam quality image of double frequency light. (a)2D image, (b)3D image.

The sum frequency experiments of single LBO crystal and double LBO crystal were carried out respectively. In order to make to maximize sum frequency conversion efficiency, we still need the frequency doubling light experimental data is used to calculate the best sum frequency crystal length. The operation method with the KTP double frequency crystal length calculation method is the same, the second piece of LBO with the first piece of LBO use the same optimal sum frequency crystal length is the same, both is 10 mm. When a single LBO crystal is used for 355nm sum frequency experiments, with the maximum pumping voltage reaches 800V, the maximum output energy of 355nm ultraviolet light reaches 30mJ, and the conversion efficiency from 1064nm to 355nm sum frequency light is 12.4%. Then we carried out sum frequency experiments with double LBO crystal, in the experimental process, we used two placement methods to conduct a comparative study on the double LBO. The first way is to place two LBO crystals at an angle of 0 degree, which is equivalent to extending a single LBO crystal to 2 times; the second way is that the angle between the optical axis of the second LBO crystal and the optical axis of the first LBO crystal is equal to twice the optimal phase, that is2θm. When the first placement method was used for the experiment, with the maximum pumping voltage was 800V, the uv light output of 355nm was only 0.89mJ. It can be seen that simply equivalent growth of LBO crystal length will not improve the sum frequency conversion efficiency. In order to improve the conversion efficiency of sum frequency, we further adopted the second crystal

placement scheme to continue the 355nm sum frequency experiments. Figure 6 shows the relationship between the output energy of 355nm with pump voltage when the second placement scheme of dual LBO crystals is used for 355nm sum frequency experiments. It can be seen that, when the maximum pumping voltage reaches 800V, the maximum output energy of ultraviolet light at 355nm can reach 44.2mJ, and the conversion efficiency from 1064nm to 355nm is as high as 18.2%. Compared with single LBO crystal, the output energy of 355nm ultraviolet light is 14.2mJ higher, and the conversion efficiency is 5.8% higher. Figure 7 shows the spectral of 355nm ultraviolet laser. Finally, the maximum output energy of 355nm was 44.28mJ, pulse width was 10.08ns, and repetition frequency was 1Hz.

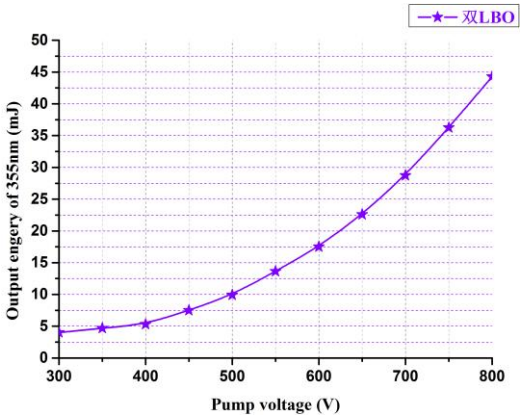


Figure 6. The relationship between the output energy of 355nm with pump voltage

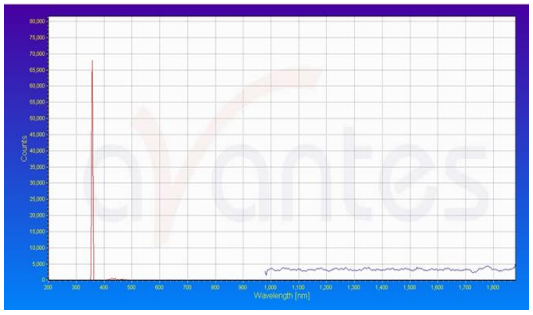


Figure 7. The spectral of 355nm ultraviolet laser.

3. Conclusions

The experimental results strongly prove the feasibility and correctness of this method, which is adopted for the first time in this paper. The angle of the main optical axis of the two LBO crystals is equal to twice phase matching angle, then obtained the 355nm ultraviolet light output by the sum frequency conversion. It is also confirmed that this method makes full use of 1064nm fundamental frequency light and 532nm double frequency light while compensating the walk angle. Finally, the output power of 355nm laser and the conversion efficiency of total light were effectively improved. The double LBO crystals sum frequency scheme not only compensates for the shortcoming of the traditional sum frequency method, but also provides a theoretical basis and reference experiment for a new method to improve the frequency conversion efficiency.

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