

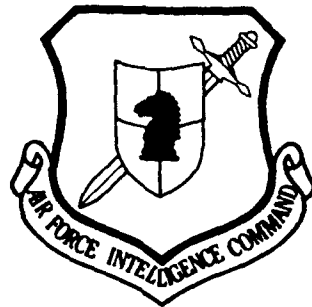
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EXTRACAVITY FREQUENCY DOUBLING STUDY OF A PULSED
PHOTODISSOCIATION IODINE LASER

by

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Extracavity Frequency Doubling Study of a Pulsed
Photodissociation Iodine Laser

Sun Yizhu, Jin Yuqi, and Cui Tiehi
(Dalian Institute of Chemical Physics, Academia Sinica, Dalian)

Abstract An extra-cavity lithium metaniobate (LiNbO_3) crystal and the angle-phase matching technique were used for extracavity frequency doubling investigation of a pulsed photodissociation iodine laser. Frequency doubled laser beam of $0.657\mu\text{m}$ wavelength and maximum energy conversion efficiency of 9.6% were obtained.

(Manuscript of this paper was received on November 8, 1989.)

Recently, non-linear effect has been applied to expand the laser wavelength range and significant progress has been made. Along with the development of laser-induced nuclear fusion reaction research, a visible laser is required to enhance the coupling of laser on the target. Extensive study of frequency-doubling of Nd YAG laser devices has been carried out and extracavity Nd YAG frequency-doubling cavity conversion efficiency of 57% has been reported.[1] Recently, lithium iodine was used by US Air Force Weapon Laboratory for extracavity frequency-doubling oxygen-iodine laser research and an efficiency of 5 to 10% was achieved.[2] The research described in this paper is the first frequency-doubling study of photodissociation iodine laser carried out in China and satisfactory results were obtained. It provided a new laser technology to be used in laser-induced nuclear fusion research in China.

Experimental Set-Up

The laser device used in this study was a pulsed photodissociation iodine laser device. [3] Laser pump was the coaxial pulsed xenon lamp (FL) which was a 50x660mm quartz tube. The electrodes of the xenon lamp was 16 (8 for each electrode) 3x10mm cerium-tungsten rods, which had the advantage of stability and extended service life. The excited medium I^* was obtained by photodissociating CF_3I by pulsed xenon lamp. Laser tube (LT) was made of $\Phi 30 \times 920$ mm quartz tube with Brewster windows (W) on both ends to ensure polarized output light. Focusing cavity (FR) was made of hard plastic material and aluminum foil was used as the reflection film. The cavity was capable of high efficiency laser beam concentration. Resonance cavity was composed of concave total reflection ($R=5m$) and output (plane) medium film mirrors (M_1 and M_2) with length of 1520mm. Under the condition of best coupling ($T=8\%$), the maximum output energy for 1.315 μm base wavelength was 488mJ/pulse and the pulse width was 100 μs .

Lithium metaniobate (LN) crystal was used as the non-linear material for secondary resonance wave. The crystal was placed outside the pulsed photodissociation iodine laser resonance cavity and angle-phase matching method was utilized. The LN crystal was cubic in shape with base length of 10mm.

The experimental set-up was illustrated in figure 1. The 1.315 μm base wavelength output from iodine laser was split by beam-splitting mirror M_3 ($T=4.5\%$). One of the split beams was focused by a lens L_1 with $f=280$ mm and was received by M172 laser

energy receiver. Another split beam was focused on LN crystal by a lens L_2 , with $f=70\text{mm}$ so that the b axis of the crystal was perpendicular to the direction of travel of the laser beam while the a or c axis of the crystal was parallel to the beam. The output light passed through lens L_3 ($f=30\text{mm}$) and was converted to parallel-traveling light beams. The parallel beams went through K , glass prism and different wavelengths were separated. The $1.315\mu\text{m}$ infrared light was blocked and the remaining $0.657\mu\text{m}$ red light was focused by lens L_4 ($f=60\text{mm}$) and was received by LPE-1 laser energy receiver.

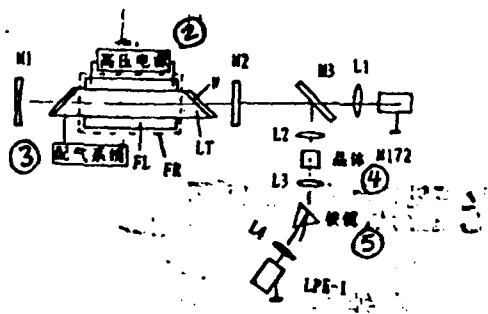


Figure 1: Experimental set-up

- 2 - high voltage power supply
- 3 - gas mixture system
- 4 - crystal
- 5 - prism

When the measurement was carried out, the readings of the two energy receivers were recorded. The energy of the base wavelength light was calculated based on the transmittance of the beam splitting mirror and the frequency-doubling efficiency was calculated as $\eta = J_1 / J_0$, where J_1 is the frequency-doubling output energy and J_0 is the base wavelength input energy.

Experimental Results and Discussion

The experimental data are listed in table 1. These results were obtained based on xenon lamp pressure 70torr, discharge voltage 10kV, and laser tube CF₃I pressure 40torr.

Table 1: Experimental measurement result

| experiment no. | base freq. power (mJ) | double freq. power (mJ) | conversion efficiency (%) |
|-------------------|-----------------------|-------------------------|---------------------------|
| 1 | 445.7 | 42.8 | 9.6 |
| 2 | 407.5 | 36.4 | 8.9 |
| 3 | 456.3 | 35.5 | 7.8 |
| 4 | 488.1 | 37.0 | 7.6 |
| average and error | 449.4±3.2 | 37.9±3.3 | 8.5±0.9 |

From the data in table 1, it can be seen that the maximum frequency-doubling efficiency was 9.6%. A relative error of ±7.4% was caused due to output energy instability of base-frequency laser, leading to a corresponding error in frequency-doubling wavelength of ±8.7% and an error in conversion efficiency of ±10.6%. The instability in output energy of base-frequency laser was mainly because of the fluctuation of output of xenon lamp as a result of high voltage discharging.

The frequency-doubling conversion efficiency was closely related to matching angle. The efficiency is

$$\eta = \eta_{\max} ((\sin \Delta K / 2) / (\Delta K / 2))^2$$

where η_{\max} is the conversion efficiency when the angle is at the matching angle, $((\sin L\Delta K/2)/(L\Delta K/2))^2$ is the corresponding factor, L is the dimension of the crystal, and ΔK is the phase matching factor.

In order to obtain high efficiency, we used lens L_2 in this experiment to focus laser beam and to increase the power density. At the same time, the problem of photodamage of the crystal was also considered. The LN crystal used in our experiment had been damaged by laser beam. Based on the pulse energy (448mJ) of the base-frequency laser beam and the damage area ($D=1.6\text{mm}$) of the crystal, the power damage threshold and energy damage threshold of the LN crystal were calculated to be $2.4 \times 10^5 \text{W/cm}^2$ and 24J/cm^2 , respectively. The damage threshold of our LN crystal was much lower than that reported in the literature. One of the possible reasons of this low damage threshold was surface stain on the crystal.

References

- [1] Byer, Laser Focus, No. 1, 8 (1988)
- [2] AW&ST, May 15 (1989)
- [3] J. F. Tong, Applied Laser Technology, 6, 1 (1985)

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