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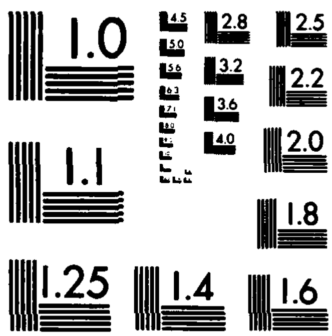


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# FOREIGN TECHNOLOGY DIVISION

A FAST DISCHARGE EXCIMER LASER WITH SYMMETRIC GEOMETRY

BY

Su Yao Wen





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# A FAST DISCHARGE EXCIMER LASER WITH SYMMETRIC GEOMETRY*

Su Yao Wen (Institute of Electronics, Academia Sinica) /104

Up to date, the excimer lasers pumped by Blumlein circuit are mostly having an asymmetric geometry using single plate capacitors to store the energy. The experiments of Schwab, et al. [1] on $N_2$ gas lasers showed that poor spatial symmetry of the laser beam is obtained from the single plate asymmetric laser. Beams with good spatial symmetry can be obtained from lasers of double plate structure. We have constructed a fast discharge excimer laser with symmetric geometry using glued and hot pressed double plate capacitor for energy storage. With this device, $N_2$, XeF and KrF lasers with good spatial symmetry were obtained. Preliminary study on the parameters of the XeF excimer system was carried out with this experimental device.

## I. DESIGN CONSIDERATION AND EXPERIMENTATION

For obtaining good spatial symmetry of the laser beams, we have made the laser with symmetric geometry using double plate flat capacitor for energy storage. This structure conforms with the requirement of minimum inductance of the pump circuit since the intrinsic inductance of the double plate capacitor is about 1/4 of that of the single plate capacity. The double layer structure has also the additional advantages of small size, large activation volume, safe in operation and low high frequency magnetic radiation during operation. Figure 1 shows the cross-section of the laser.

Since the inductance of the main discharge is mainly due to /105
the spark gap switch, it is very important in design and installation of the spark gap switch. We designed a gas filled triode spark gap switch which could be directly installed with the double plate flat capacitor. The trigger of the cathode was made from the

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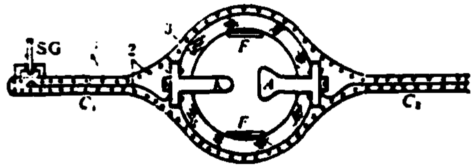


Figure 1. Cross-section of fast discharge excimer laser
K--anode; A--cathode; F--flashing plate; SG--spark gap switch; 1--copper foil; 2--insulator; 3--laser tube; $C_1$, $C_2$--glued and hot pressed thin film Dacron capacitor, $C_1$ =8.4 nF, $C_2$ =17.4 nF

(a) (b)

Figure 2. The XeF laser spots at different distances from the output lens.
(a)--at 35 mm; (b)--at 88 mm

common sparkplug. The whole switch portion was connected to the transmission line to form the main discharge circuit without using any conductor. This is so designed to minimize the inductance of the circuit to the extent possible.

In order to obtain a uniform discharge glow under high pressure, we employed an ultraviolet ray for pre-ionization in the laser chamber. The tube for the laser was made from epoxy-glass composite cloth and had an inside diameter of 8.4 cm and a length of 88 cm. Plexiglass flanges were used on both ends as clamps for the reflecting mirrors. The optical resonance chamber consisted of a concave mirror, having a radius of curvature of 4 m, coated with totally reflective film and an output flat lens. The distance between the mirror and the lens was 95 cm.

The main electrode of the laser was made of aluminum. The radius of curvature of the cylindrical cathode, $r_c$, was 2 mm. The anode was a flat electrode with 1 cm in width. The distance between the electrodes was 1.7 cm. The effective length of the electrode was 75 cm. It provided 60 $cm^2$ activation area. The distance between the pre-ionization flashing plate and the center axis is 3.5 cm. The time delay between the pre-ionization discharge and the main discharge was about 200 ns. This was accomplished by using a SYV-75-1 cable of 40 m in length.

## II. EXPERIMENTAL RESULTS

We measured the electrical characteristics and took some photographs using OK-19$M_2$ high voltage oscilloscope. The intrinsic inductance of the main switch is ab o ut 6.6 nH as determined from the waveform of the discharge voltage of the spark gap switch of the main discharge circuit. Figure 2 shows the XeF laser spots. The laser intensity is about 5 mJ. The symmetry of the laser beam is relatively good. It also shows that the angle of divergency of the laser beam is higher along the discharge direction than that on the vertical direction. Figure 3 shows the spectra of XeF and KrF lasers obtained using a WPP-05 planar grating spectrograph. The XeF spectrum shown in Figure 3(a) displays clearly the typical structure of discrete energy levels of the excimer lasers, while the KrF spectrum shown in Figure 3(b) exhibits a structure of continuous distribution. The difference is due to that the energy level of the XeF laer is in a bonding state while that of the KrF laser is in an exclusion state.

We carried out some initial experiments to investigate the effects of various parameters on the output of the XeF laser. The output coupling was 20% in all experiments. There was also some laser output at the end with the totally reflecting mirror. The maximum output of the XeF laser was 30 mJ with an efficiency of about 0.6% (the corresponding operation conditons were $NF_3$(1.5 Torr)/Xe(12 Torr)/Ne(balance), total pressure: 1.45 atm, charging voltage: 20 kV, delay duration: 200 ns). The photosensitive material on the receiver of the photoelectric cell in the photoelectrometer was vaporized by the laser pulse at such maximum condition.

(a) (b)

Figure 3. Spectra of the XeF and KrF lasers

(a) Spectrum of the XeF laser, width of the grating opening 14 μm, single pulse exposure, from left to right: 3488Å, 3510Å, 3532Å, corresponding Fe spectrum-grating opening: 25 μm, exposure: 60s

(b) Spectrum of the KrF laser, grating opening: 8 μm, single pulse exposure, wave length of the intensive center line: 2483.5Å, line width: about 6 Å, wave length of the weak line: 2491Å, the corresponding Fe spectrum-grating opening: 20 μm, exposure: 60s

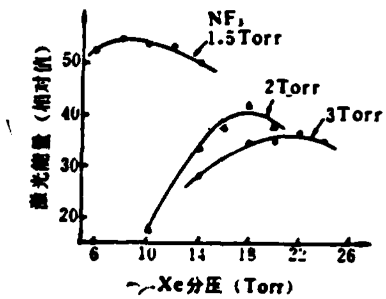


Figure 4. The effect of the partial pressure of Xe on the output of the XeF laser.
(total pressure: 1.45 atm, charging voltage: 20 kV, $NF_3$ content <0.2%, optimum Xe content: ≤1%)

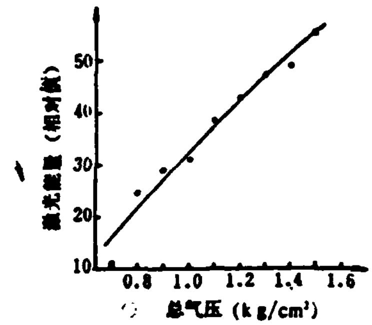


Figure 5. The effect of the total pressure on the output of the laser ($NF_3$: Xe:Ne=0.13:0.87:99, charging voltage: 20kV)

1--energy of the laser beam (relative value); 2--total pressure (kg/cm$^2$

Figure 4 shows the relation between the output of the XeF laser and the partial pressure of Xe. It indicates that there is an optimum partial pressure of Xe for each $NF_3$ content under fixed total pressure. It also shows the existence of an optimum ratio of the partial pressure of Xe to that of $NF_3$. The ratio is 5-7 as determined in our experiments. Within the testing ranges of our experiments, the pulse energy of the laser increased linearly with increasing total pressure and saturation was not observed even at a pressure of 1.5 atm. Figure 5 shows the effect of the total pressure on the output of the laser (no experiment was carried out at higher pressure due to the requirement of additional modifications).

The output of the laser is also related to the capacitor for energy storage. Figure 6 shows the effect of the charging voltage of the energy storage capacitor on the output of the laser. The energy of the pulse increased with increasing charging voltage. Figure 7 shows the effect of the charging voltage of the capacitor in the pre-ionization circuit on the output of the laser. The influence is relatively small. Severe arcing will occur and no output of the laser can be obtained under the operation condition of high pressure without the pre-ionization.

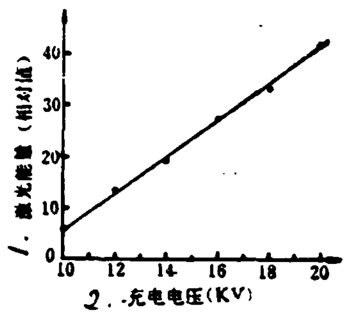


Figure 6. The effect of charging voltage on the laser output ($NF_3$(1.5 Torr) /Xe (8 Torr)/Ne(balance), total pressure: 1.45 atm, fixed pre-ionization voltage)
1--energy of the laser beam (relative value;
2--charging voltage (kV)

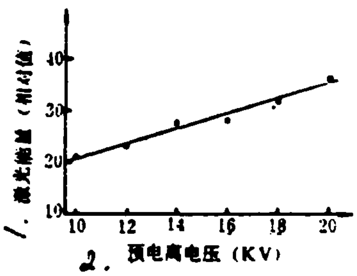


Figure 7. The effect of pre-ionization voltage on the output of the laser (total pressure: 1.45 atm, capacitance of the pre-ionization capacitor: 40 nF fixed main discharge voltage: 20 kV)


The author wishes to express his appreciation to Mr. Yang Jing-tao for the assistance in carrying out the experiment and to Mr. Liu Dian-you for his help in making the glued and hot pressed capacitor.


## REFERENCES


[1] A. J. Schwab, et al.: IEEE Vol. QE-12, No. 3, p. 183, 1976.
[2] C. P. Wang: Rev. Sci. Instrum. Vol. 47, No. 1, p. 92, 1976.

**Abstract:** A fast discharge rare gas halide excimer laser with symmetric geometry pumped by glued and hot pressed capacitor is introduced. Laser beams with good spatial symmetry are obtained. By the device, lasings at $N_2$ 3371Å, XeF 3488,3510 and 3532Å and KrF 2484Å were achieved. Detailed experimental results on the XeF system are also given.

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