Laser Letter 1

1.2-J XeCl Laser Excited by Electric Discharge

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High-power laser action on the 308-nm band of XeCl excimer excited by electric discharge is reported. A double pulse forming line formed by two parallel flat-plate water capacitors is terminated by a TE laser tube through a double surface gap. An output energy of 1.2 J (60 ns FWHM) per pulse is obtained for a mixture gas of HCl: Xe: He = 3: 20: 2600 Torr. The output energy increases by a factor of 1.67 compared with the traditional single pulse forming line.

The laser efficiency on the 308-nm band of XeCl excimer has remarkably increased by the use of HCl as a halogen donor instead of Cl₂.¹⁾ An output energy of 180 mJ has been obtained with a fast discharge pumping device which gave the 260-mJ output energy for KrF.²⁾ We have reported that a XeCl laser is more efficient pumping source of dye lasers than a KrF laser,^{3,4)} and that a XeCl laser radar is very useful for the detection of the stratospheric ozone layer.^{5,6)}

In this letter, a discharge pumped XeCl laser with an output energy of 1.2 J (60 ns FWHM) per pulse is reported. Its construction is similar to the 0.8-J KrF laser recently reported by Taylor *et al.*⁷⁾; however, a new scheme ‘the double pulse forming line (PFL)’ is employed, by which the output energy increases by 67 % compared with the traditional single PFL.

Two laser systems were made. A schematic diagram of the first system is shown in Fig. 1. We call it 'the double PFL system'. The PFL was charged by a 200-kV, 4-stage Marx-bank generator. A 0.22- μF , 50-kV low inductance capacitor was used for each stage of the Marx-bank. The double PFL is formed by two parallel flat-plate water capacitors, whose size was 70 (length) $\times$ 84 (width) $\times$ 2 (thickness) cm^3 and calculated capacitance was 0.02 μF per sheet. Ion-exchange water was continuously circulated.

Two PFL's were connected to the TE laser tube through a double surface gap,^{7, 8)} as shown in Fig. 2. Each surface gap has thin aluminum

Fig. 1. Schematic diagram of double PFL system.

Fig. 2. Cross section of double surface gap. The electrodes are 0.3 mm thick and 84 cm wide.

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electrodes symmetrically contacted on both sides of a Teflon insulator. The gap was 2 cm long and 84 cm wide, and nitrogen gas was filled. 92-cm long main electrodes were made of stainless steel with a Chang's profile, and were put in a lucite housing with a gap length of 4cm. 46-spark-gaps array for preionization was fed from a 0.15- μ F storage capacitor. The optical cavity consisted of a 6-m-radius dielectric mirror and a quartz plane tube-window.

The second one, 'the signal PFL system', had a sheet of plane water PFL with a size of 76 (length) $\times$ 88 (width) cm^2 , and the thickness L was variable. The surface gap was single in this case. Other components such as the Marx-bank, the laser tube and the preionizer were common in both systems.

The charging voltage of the PFL was measured by a Tektronix 519 oscilloscope and CuSO_4 voltage dividers. The laser energy was measured by a calibrated thermo-pile (TRG-100).

The Marx-bank generator and the preionizer were simultaneously triggered. The main discharge started at about 0.5 μs after triggering. This delay time was almost optimum and very stable uniform glow discharge was observed up to a total gas pressure of 3.5 atm. The peak charging voltage of the PFL was controllable by the surface gap pressure. The maximum laser output energy was obtained at a pressure of 2 atm for the double PFL system and 1 atm for the single PFL system. Although the charging voltage increased for higher pressures of the surface gap, the laser efficiency decreased due to the degradation in multichannel discharge of the surface gap.

Figure 3 shows the 308-nm laser output energy as a function of the total gas pressure for HCl/Xe/He mixtures. The output energy increases steadily up to 3.5 atm. The E/P-value is 4.3 kV/atm-cm at 3.5 atm. Figures 4 and 5

Fig. 3. Laser output energy as a function of total gas pressure for HCl/Xe/He mixtures. The double PFL system was used at an input voltage of 140 kV.

Fig. 4. Output energy, overall efficiency and peak charging voltage of PFL as a function of charging voltage of Marx-bank generator. The single PFL system was used for a mixture gas of HCl: Xe: He = 3: 7: 2600 Torr. The surface gap pressure is 1 atm.

Fig. 5. Output energy, overall efficiency and peak charging voltage of PFL as a function of charging voltage of Marx-bank generator. The double PFL system was used for a mixture gas of HCl: Xe: He = 3: 20: 2600 Torr. The surface gap pressure is 2 atm.

show the laser output energy, the peak charging voltage of the PFL, and the overall efficiency (energy for preionization is excluded) vs. the charging voltage of the Marx-bank generator. The maximum output energy 1.2 J was obtained for the double PFL system at the 160-kV input voltage. The mixture gas was HCl: Xe: He = 3: 20: 2600 Torr. The pulse width measured by a biplaner phototube (HTV-R-617) was approximately 60 ns FWHM. In Fig. 6, a direct burn pattern on an exposed Polaroid film is given, which shows that the active region is approximately 1.5 cm wide, therefore the specific energy extraction is 2.2 J/liter.

Fig. 6. Direct burn pattern on an exposed Polaroid film by laser beam. The central dark region is burnt more deeply. The double PFL system was used for a mixture gas of HCl: Xe: He = 3: 20: 2600 Torr. The output energy was approximately 1.2 J. UV preionization light is radiated from the right hand side.

Although the output energy increases monotonically as a function of the input voltage, the overall efficiency reaches its maximum value of 0.31 % for the double PFL system when the output energy is 0.6 J. The efficiency is improved by a factor of 1.67 compared with

the single PFL system at an input voltage of 140-kV. Such improvement is not explained by decrease in the characteristic impedance Z_0 of the PFL. Z_0 of the double PFL for $L=2$ cm is 0.5Ω , which is equal to that of the single PFL for $L=1$ cm. However, the output energy of the single PFL was rather decreased by reducing L from 2 cm to 1 cm, as shown in Fig. 4. We believe that the increase in output energy for the double PFL is mainly due to the decrease in the inductance of the main discharge circuit including the surface gap.

For the KrF system more efficient laser action is expected. To increase the filled gas pressure will also be effective. We are making an experiment on amplification of picosecond pulses with this high-power XeCl laser. Picosecond pulses at 308 nm are generated by a frequency-doubled flashlamp-pumped Rhodamine 6G laser. Picosecond GW pulses in the UV are expected to be obtained.

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