

AN IMPROVED DISCHARGE TECHNIQUE FOR EXCIMER LASERS

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The further development of discharge excimer lasers depends upon a better degree of control over the discharge stability. A problem is the large difference between the breakdown and steady-state voltage which requires a time dependent impedance of the power circuit. Further the large attachment rates of halogens like HCl, causing electric field disturbances require a short rise time of the applied current pulse. A large effort has been expended towards this goal by researchers since the early development of discharge excimer lasers.

A breakthrough in this development was obtained by the introduction of the so-called prepulse-main-pulse technique in which the prepulse is used for the avalanche ionization process during the breakdown phase whereas the main pulse is applied under quasi-steady state conditions [1-3]. Although this technique was introduced by using a rail gap to separate the circuits further improvements were obtained with passive magnetic switches [2,3]. There is a choice of two polarities for the prepulse circuit with either a current reversal in the magnetic inductor or a current reversal through the discharge. In the first case there is a delay because of the saturation process in the switch and in the second case a larger magnetic core area is required which gives a larger saturated inductance. In both cases the main pulse is hampered by a rise time which is too long with respect to the electron attachment rate and the streamer formation time causing a decrease of discharge quality.

The present contribution describes an improvement of the excimer laser discharge technology. It allows for a much better adaptation of the circuits to the discharge with minimum delay between prepulse and main pulse currents. Up till now an efficiency of 5% has been obtained for the conversion of the total electrical stored energy into optical radiation. Furthermore the improved discharge stability shows that

for high energy deposition the optical pulse does not terminate early before the end of the current pulse. For a discharge current of about 150 A/cm² optical pulses of about 200 ns were found.

The scheme of the electric circuit is shown in fig. 1. The PFN and the peaking capacitor C_3 are charged within a few microseconds to twice the steady state voltage (V_{ss}) of the XeCl excimer laser. The saturable inductor L_4 is the magnetic switch of the PFN to the laser. In the prepulse circuit C_2 is about equal to C_3 and charged to $-4V_{ss}$ with the indicated polarity. Switching S in approximately 1 μ s after loading the PFN it is seen that there is a ringing circuit between the C_2 and C_3 with a high impedance of L_4 . As a result the voltage of C_3 changes to $-2V_{ss}$. During this period L_4 is saturated so that the PFN (at $2V_{ss}$) is directly connected to the peaking capacitor. Since C_3 was charged to $-2V_{ss}$ it will now in principle be resonantly charged to $6V_{ss}$ in a very short time depending on the saturated inductance of L_4 .

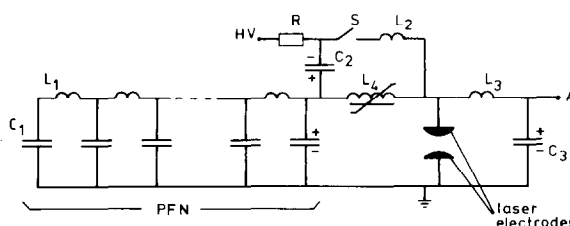


Fig. 1. Diagram of the discharge circuit.

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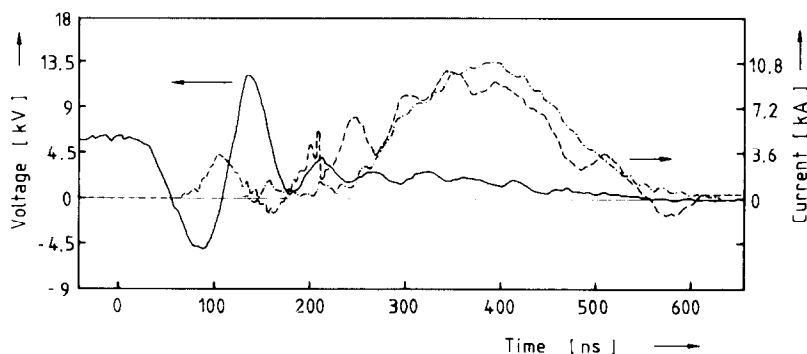


Fig. 2. Waveforms of the voltage (solid line), current (broken line) and output pulse (dashed line) of the described XeCl laser.

This occurs shortly after the X-ray preionization pulse. However even before reaching $6 V_{ss}$ this peaking capacitor acts with the laser electrodes as the pre-pulse circuit for the avalanche ionization process. Then, by reaching the characteristic impedance of the PFN, the main pulse will follow immediately because the charging current of the peaking capacity and the discharge current have the same direction. Thus there is no current reversal either in the discharge or in the magnetic inductor.

This scheme has been successfully applied to our X-ray preionized XeCl laser as described in ref. [4]. The PFN contains ceramic capacitors having a total capacity of 300 nF, a characteristic impedance of 0.3Ω and a double transit time of 160 ns. The peaking capacitance is formed by 14 parallel capacitors of 460 pF each. The saturable inductor L_4 consists of two parallel race tracks of SEI type K4 ferrite blocks and is biased externally. The laser has a discharge length of 60 cm and an electrode gap of 1.5 cm. The self-inductance between the PFN and the laserhead is about 30 nH when inductor L_4 is saturated. The cavity consists of a 5 m radius end mirror and a 70% reflectivity output mirror separated at 130 cm. The

filling gas mixture contains 2 mbar HCl, 20 mbar Xe and 4 bar Ne. With a calibrated Gentec ED500 energy meter an output energy of 0.28 J has been obtained. The PFN is charged to 5.5 kV (4.5 J) and C_2 to 17.4 kV (1.1 J) so that the efficiency is 5%. The wave forms of voltage between the electrodes, discharge current and output power of this laser are shown in fig. 2. A more detailed description of alternative circuits based on the same principle will be published elsewhere [5].

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