# High Repetition Rate X-ray Preionization Source.

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## ABSTRACT

A high repetition rate X-ray source for preionization of high-pressure self sustained laser discharges has been studied. Use has been made of a corona plasma cathode and a water cooled reflective target. A dosage of 18mRad per pulse and per joule of input energy at a repetition rate of 300Hz continuously and 1kHz burst could be obtained. A rise time of the X-ray power of 13ns has been observed.

## 1. INTRODUCTION

High pressure self sustained glow discharges operating at high repetition rates for gas laser excitation require power full pulsed ionization sources with acceptable life times to preionize discharge volumes uniformly. Especially low energy X-ray photons with energies around 35keV are very effective for the preionization of high pressure discharges like TEA $CO_2$ and excimer laser discharges. These photons can be generated by stopping 70keV electrons by a target made of high Z material like tungsten or tantalum. In this contribution we describe the performance of an X-ray generator employing a corona plasma cathode [1]. Electrons can easily be extracted from a plasma on the surface of a dielectric. The plasma is generated by accelerating electrons, emitted from sharp edged conductors close to the dielectric, along the surface of the dielectric. These electrons will liberate and ionize atoms which are loosely bound to the dielectric surface and so a plasma is formed. Energy can be dissipated in the surface plasma because of the displacement current generated by a fast rising voltage across the capacitor formed by the plasma and an electrode at the other side of the dielectric. Because of this the plasma will spread and finally cover the dielectric surface completely forming a uniform cathode with a very low work function from which electrons can be extracted towards an anode.

## 2. EXPERIMENTAL ARRANGEMENTS

Our set up is similar to the corona plasma cathode used by Scott [2], however instead of using a transmitting target foil we employed a reflective target which can easily be cooled by tap water. Furthermore we decreased the voltage across the dielectric by taking only one third of the accelerating anode voltage instead of the full anode voltage. Also we matched the impedance of the high voltage pulse generator to the load. There is experimental evidence [3] that high fields and voltage reversals across a dielectric like pyrex or quartz can cause fracturing which limits the cathode life time. For symmetry reasons we employed two corona plasma cathodes located along each side of a 0.5mm thick aluminum window which seals the vacuum vessel. Construction details are shown in figure 1. Experiments have been performed with a small prototype X-ray generator which has a $2x10cm^2$ water cooled anode which was covered by a 25μm thick tantalum foil as the high Z target. The two 10cm long corona plasma cathodes were made by winding 150μm NiCr wire around 1cm diameter quartz tubes with 1.2mm thick walls. Inside the tubes copper bars acting as the electrodes opposing the corona plasma were located. Screens were placed along the two corona plasma cathodes in order to influence the field lines to force the electrons to fall on the front surface of the anode. The complete electrical circuit is shown in figure 2. A pulse forming network made from TDK 1.7nF ceramic capacitors was resonantly charged up to 20kV and was discharged by means of a thyratron through the one turn primary of a pulse

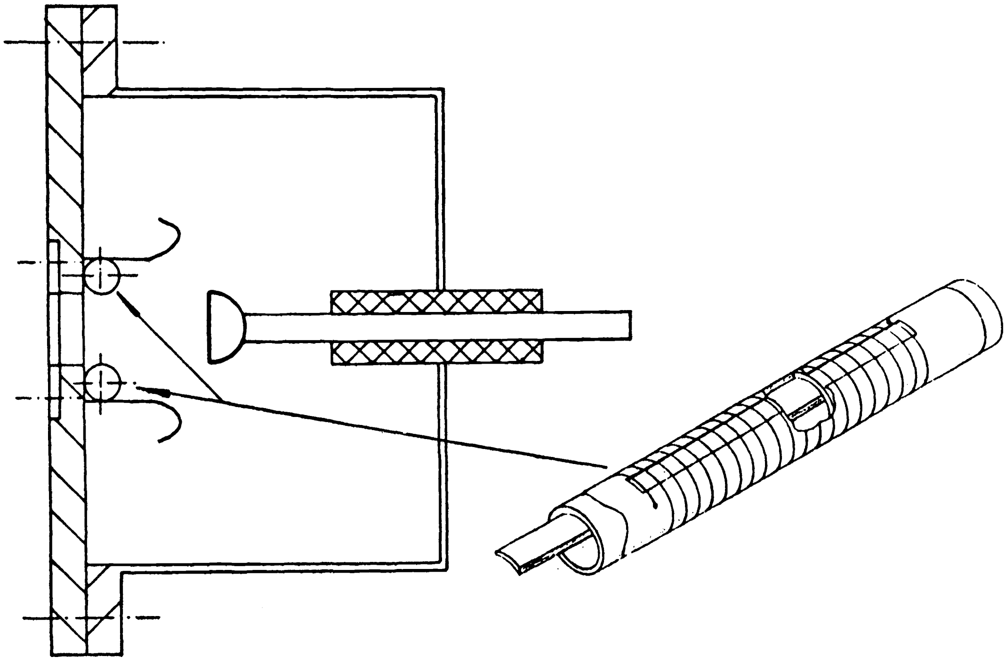

Fig. 1. Experimental set up.

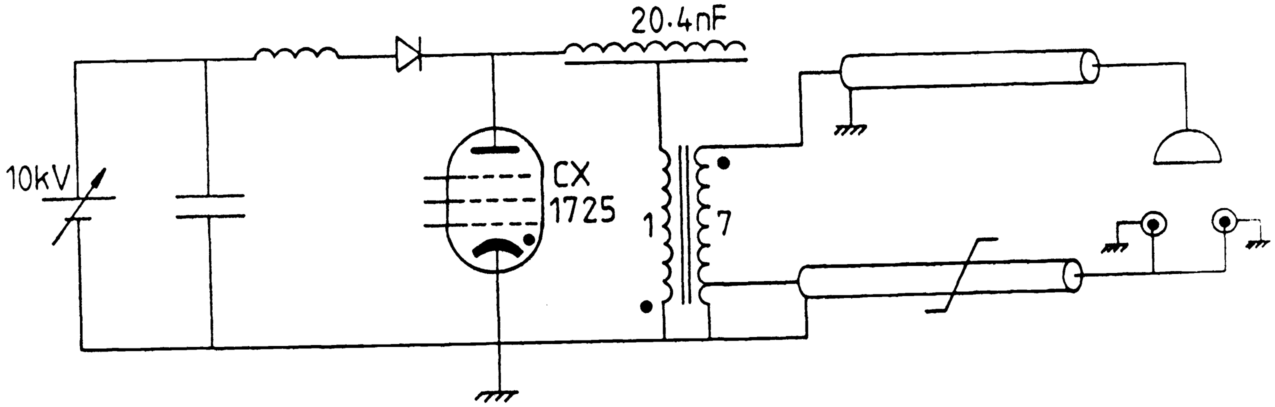

Fig. 2. Electrical circuit.

transformer. The impedance of the pulse forming network was chosen such, that the source impedance was matched to the load at a load voltage of 70kV. The pulse length could be varied by changing the number of capacitors in the pulse forming network. The anode current could be changed by altering the impedance of the pulse forming network together with the anode-cathode distance. To shorten the rise time of the voltage supplied to the trigger electrodes of the two plasma cathodes we used a ferrite loaded coaxial cable or shock line [4] which was connected to a tap of the secondary winding of the pulse transformer. In this way the corona plasma is generated very efficiently with a minimum formation time. Furthermore, the shock line provides a time delay of the trigger voltage relative to the anode voltage. The shock line was made of 3mm long Philips Ferroxcube ring cores, grade 3B, with an inner- and outer diameter of 1.2mm and 3.5mm respectively. 330 of these cores were strung on a 1mm diameter copper wire. The string was surrounded by a perspex tube of 6mm outer diameter and 1.2mm wall thickness for isolation from the grounded outer conductor.

## 3. RESULTS AND DISCUSSIONS

Figure 3 shows waveforms of the input and output voltages for 100cm and 180cm long shock lines. It can be observed that only for the 180cm line the sharpening of the input pulse has been completed, however at the cost of a longer time delay. The rise time of the trigger voltage was reduced from 112ns down to 30ns. We have chosen a 100cm long shock line in our experiments because its time delay coincides with the time needed to charge the capacitance made up by the cable connecting the pulser to the anode and the stray anode-cathode capacitance. Also the formation time of the corona plasma was only slightly improved by using the 180cm long shock line. In figure 4 typical waveforms of the anode voltage, anode current and the X-ray power are shown. The voltage was measured with a calibrated resistive voltage divider, the current with a Pearson model 110 current probe, and the X-ray power with a plastic scintillator and a photo multiplier. The rise time of the X-ray pulse was 13ns and the pulse length could be varied by changing the length of the pulse forming network of the thyratron pulser. In figure 5 the perveance measured as a function of the anode cathode distance is shown. Also in figure 5 the perveance given by the Child-Langmuir law for a space charge limited current dependency :

$$i = A \times \frac{4}{9} \varepsilon_0 \left(\frac{2e}{m}\right)^{1/2} \times \frac{V^{3/2}}{d^2} \qquad (1)$$

has been plotted for two values of A, the effective emitting cathode surface. $\varepsilon_0 = 8.8544 \times 10^{-12}$F/m and $e/m = 1.7588 \times 10^{11}$C/kg. V and d are the anode-cathode voltage and distance respectively. In figure 6 the measurements of the spatial distribution of the dosage per shot, measured with an array of eight SEQ-9 pendosi meters spaced 1.5cm and located just behind the aluminum window, are shown for several values of the input energy. The anode voltage and current were 70kV and 150A respectively, the input energy was varied by changing the duration of the (square) pulse from about 200ns up to about 600ns. Figure 7 shows the (expected) linear dependency of the dosage per shot at the center of the aluminum window as a function of the energy input.

The X-ray source operated continuously at a repetition rate of 300Hz during two hours and during bursts of one minute at 1kHz at an input energy of about 1J per pulse. No degradation of the cathodes could be observed after accumulating $5 \times 10^6$ shots. 1kHz operation had to be limited to one minute bursts because of corona problems at the high voltage cable feed through and because of heating up the ferrite shock line which was not cooled during the experiments.

## 4. CONCLUSIONS

In conclusion we have demonstrated the feasibility of a high repetition rate X-ray source using a corona plasma cathode. A dosage per shot of about 18 mRad per Joule of input energy

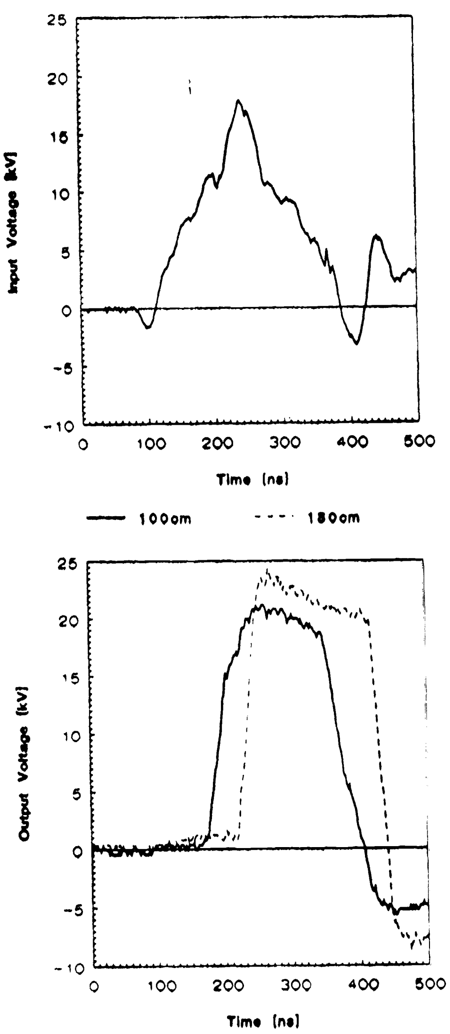

Fig. 3. Input (upper) and output (lower) voltages of the ferrite loaded coaxial pulse sharpener.

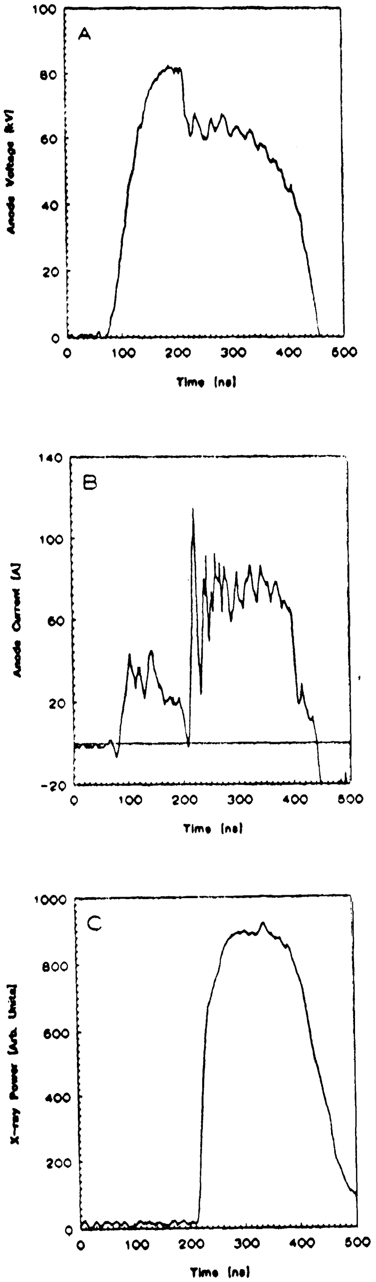

Fig. 4. Anode voltage (A), Anode current (B), and X-ray power (C) waveforms

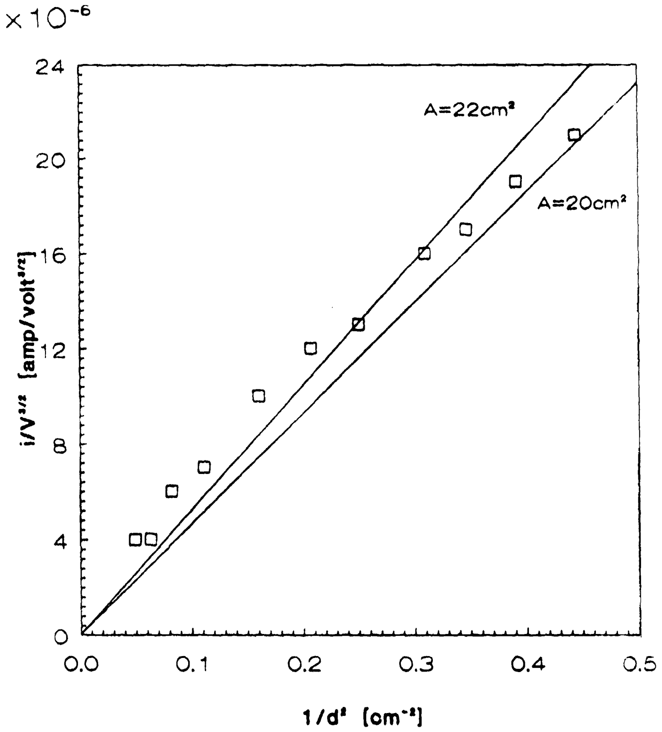

Fig. 5. Perveance as a function of the anode-cathode distance. Straight lines have been calculated using (1). Charging voltage: 10kV; PFN capacitance: 13x1.7nF.

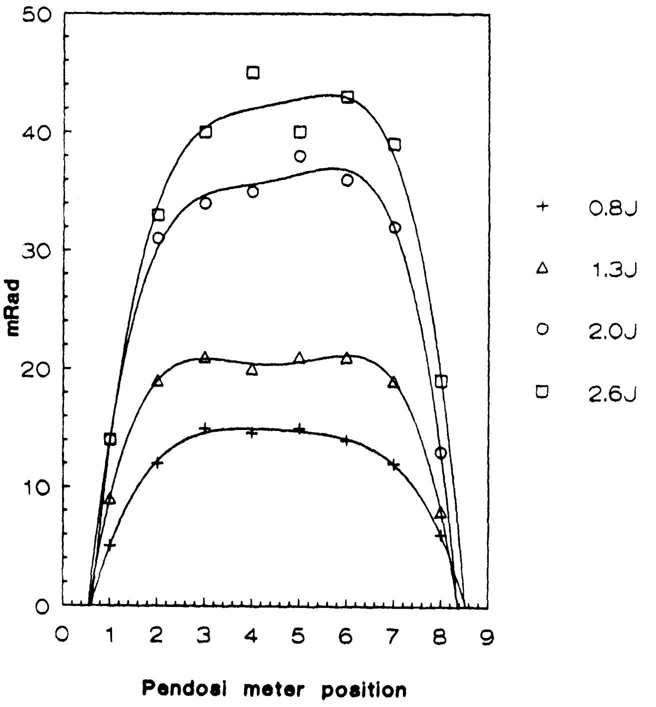

Fig. 6. Spatial distribution of X-ray dosage just behind the aluminum window. The energy was calculated by integration of the measured input power. Anode-cathode distance: 3.0cm; Charging voltage: 8kV; PFN capacitance: 5,7,9 or 13x1.7nF.

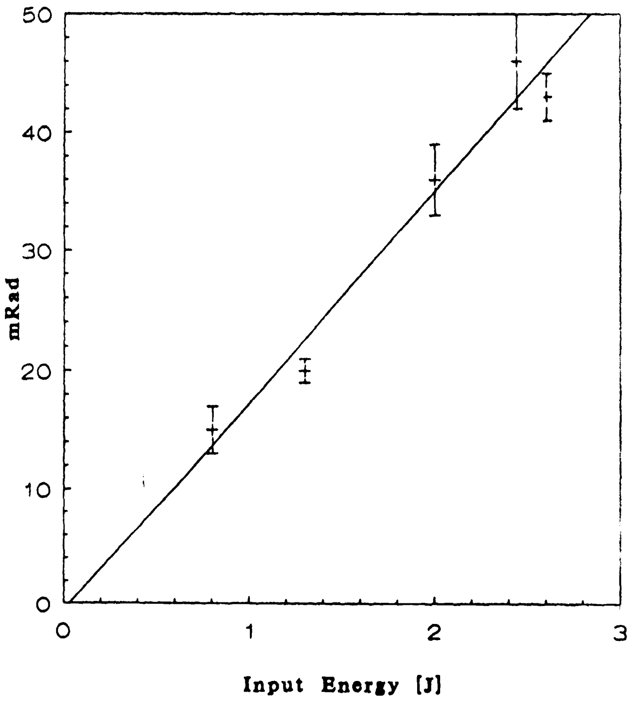

Fig. 7. X-ray dosage as a function of the input energy.
(Same conditions as in figure 6).

emits from our 2x10cm$^2$ X-ray source at an anode voltage of 70kV and an anode current of 150A. By using a shock line to decrease the trigger voltage rise time, the rise time of the X-ray power was as short as 13ns. We consider a scaled up version of this X-ray generator as a possible solution for the preionization of the 1kHz, 1kW XeCl laser system which is currently under development in our laboratory as part of the EU213 Eureka project.

## 5. ACKNOWLEDGEMENTS

The author wishes to thank Dr. Simon Scott for many help full discussions and H.Th.M. Prins and G.J.M. Oude Meijers for their technical assistance during the experiments.

This project was supported by the Dutch Centre of Laser Research, Enschede, The Netherlands.

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