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Measurements of the Basic Characteristics of the Dense Plasma Focus Device

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Abstract. In the experiments with the 3 kJ plasma focus device at the Sofia University are measured the basic characteristics, namely the discharge current, the current derivative, the soft X-ray and the hard X-ray emission from the plasma. The average dose of the X-Ray emission is a few tenth of Sv per shot. A study of the influence of soft X-rays upon biologic objects has been started.

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1 Basic Measurements with the Plasma Focus Device

1.1 Experimental setup

In the Faculty of Physics at the University of Sofia a Mather's type dense plasma focus device (DPF) is in regular operation from about one and a half year. In the experiments with this device it is possible to obtain the quantitative results of the typical processes in a small DPF machines. As every usual DPF, it consists of a capacitor bank, fast switch and vacuum chamber, containing the electrode system. The capacitor bank has capacitance of 20 μF, with the maximal DC voltage of 40 kV. The insulator is molten quartz; the main switch is a vacuum spark gap. Only a brief description of the device will be presented here. More details for constructions and principles of operation of different PF machines are given in [1].

A procedure for optimizing the discharge conditions was carried out, changing the charging voltage and the gas pressure. So far the experiments were conducted in air. Thus the voltage operating range is 15–18 kV, and the nominal pressure is in the range of 1.0–2.0 mBar.

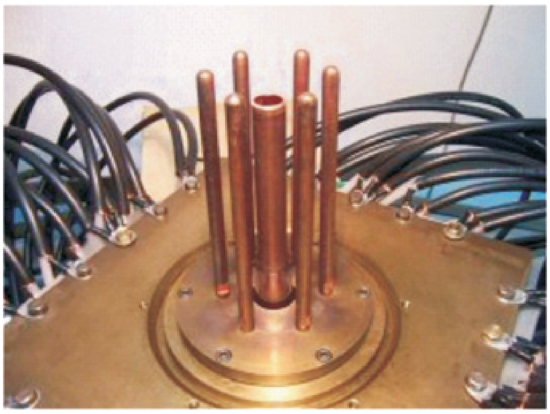

Figure 1. Mather's type electrode system; hollow anode, cathode rods and quartz insulator.

We are recording the discharge current, the current derivative, the soft X-ray and the hard X-ray emissions from the plasma. The data, received by the diagnostic tools in the first several hundred shots fired so far, reveal the typical peculiarities known from the literature for devices of this energy range (3–5 kJ): The oscilloscope pictures give the moment of the initial breakdown of the gas, followed in a few microseconds by the occurrence of a pinch.

A correlation between the observed one or more peaks of soft and hard X-rays and the peculiarities of the dI/dt signal is established, the latter corresponding to the same number of pinches with the same mutual distance in time. More than one pinch is a situation typical of a DPF, operating with relatively heavy gasses, such as Nitrogen or Argon. On the other side, when working with Hydrogen

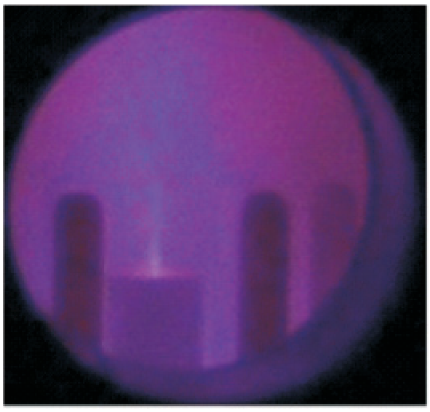

Figure 2. Photograph of a shot with the same electrode system.

(including Deuterium and Tritium) or Helium, as a rule, only a single or two pinches take place [1].

Figure 1 shows the electrode system of the device with removed discharge chamber. Figure 2 shows a photograph of the discharge taken with usual camera. The bright spots above the anode correspond to the two successive pinches of one discharge pulse.

Hard X-radiation is recorded by a plastic scintillation detector with PMT 56 TVP (Phillips).

From the signals of the mounted 4 PIN BPX 65 photo diodes we achieve useful information about the soft X-ray emission of the pinch plasma. In front of each photodiode metal filters with different thickness are placed (10, 20 and 30 μm Aluminium and 0.5 mm Lead, respectively), transmitting only radiation with energy above certain values.

These signals are in direct accordance with the number of contractions and with the soft X-ray yield. They depend also on the operating pressure and voltage [2]. We are considering as X- ray signals the sharp peaks with a half width between 100 and 200 nanoseconds appearing almost simultaneously with the hard X-ray signals.

1.2 Measurements

The two scope graphs below are from the experiment with the mentioned device when air is the working gas (nitrogen is the main component). Figure 3 shows the signals from PIN diodes (blue and red trace) and signal from the scintillation detector- green trace.

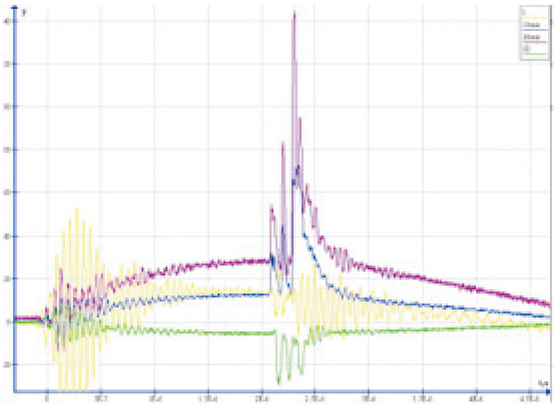

Figure 3. Signals from PIN detectors (10 μ and 20μ Al filters) a scintillation detector (green): three contractions are visible.

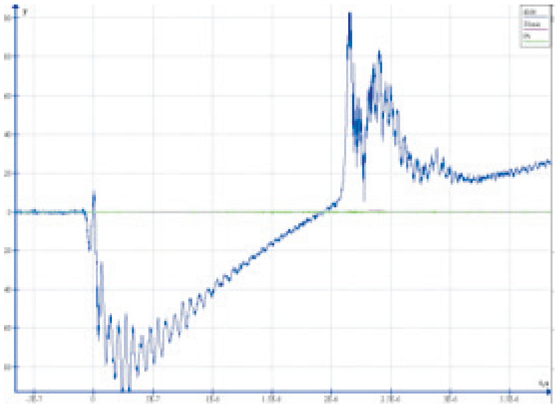

Figure 4. The current time derivative, showing also three contractions.

The current time derivative is probably the most important characteristic of a pinch discharge. The peculiarities on the curve (Figure 4) near 2.5 microseconds from the beginning show the pinch and the sharp rise of the current impedance.

It also appeared that the soft X-ray peaks were a little bit delayed (100–200 ns) from the relevant pinch moments on the dI/dt graph, and the hard X-ray peaks were delayed another 100 ns. The latter delay probably is due to position of the anode top which is about 2 cm below the tops of the cathode rods.

From shot to shot fluctuations of the peak positions in time are observed.

Adding a brass solid end to the hollow anode resulted in increased hard X-ray

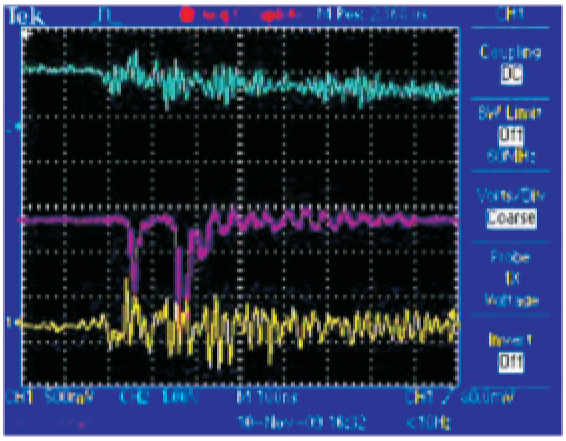

Figure 5. The violet curve (in the middle) is the signal of scintillation hard X-ray detector when working with hollow anode.

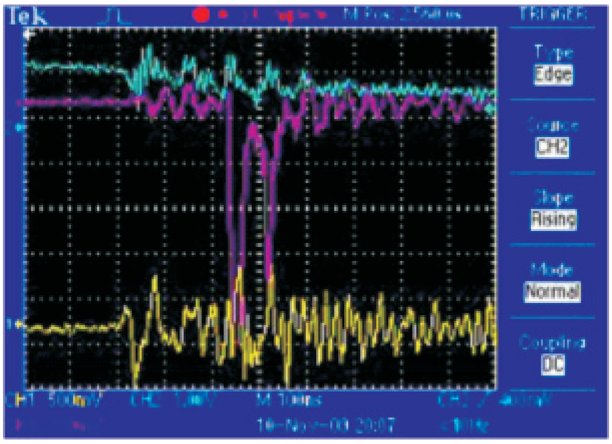

Figure 6. A shot in similar conditions, but with a solid brass end added to the anode. The considerable increase of the hard X-ray emission is evident.

yield at the same conditions. This is clear from the oscilloscope graphs shown below (Figure 5 and Figure 6). The intensity of the soft X-ray radiation is proportional to the integral of the experimental curve in the peak boundaries. It is observed that the intensity decreases with the increasing of the filter thickness.

The next two graphs (Figures 7 and 8) were taken in slightly different conditions with respect to the previous. The gas pressure is changed in the limits allowing deriving stable pinches. There are three peaks, delayed at about 200 ns from the beginning of the pinch phase.

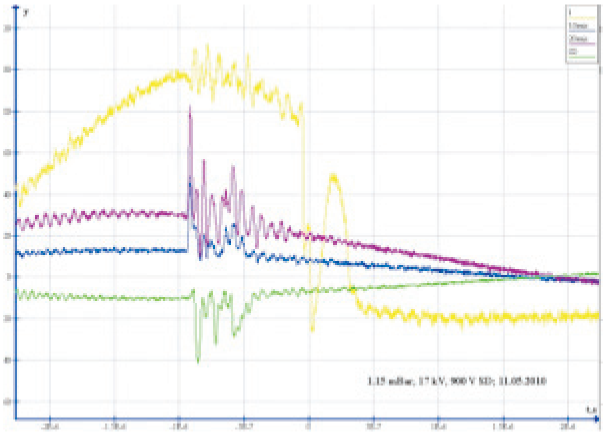

Figure 7. PIN, SD and current signals at relatively low pressure of the gas (1.15 mBar). Compare with Figure 8.

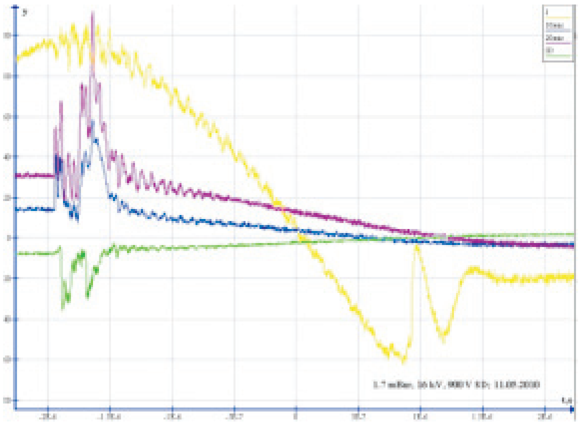

Figure 8. PIN, SD and current signals at higher pressure (1.7 mBar).

With thermoluminescent dosimeters (TLD) we have found that the full X-ray dose inside the stainless steel chamber of our DPF is in the order of a few tenths of 1 Sv per shot, while outside it is close to the natural ionization (gamma) background.

2 First Biologic Experiments with DPF at the Sofia University

The aim of these first experiments is to test the survival enzyme activity of the yeast exposed to the radiation of the X-ray emission of the PF machine. For the

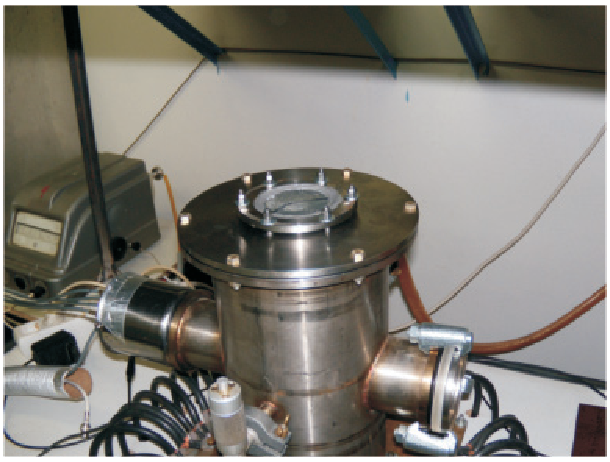

Figure 9. Upper part of the PF chamber with the port on its top used for biological experiments.

purpose a special port on the chamber top (see Figure 9) was used. It is formed like a shallow "dish" that can keep a certain amount of the liquid substance. The bottom of this vessel is made from 100 μm thick Aluminium foil supported from beneath with stainless steel mesh. The water solution of the yeast was poured in the vessel. The samples have been irradiated by soft X-rays with different number of shots. For the control of the dose obtained a TLD was placed near the samples. An X-ray film was also positioned there.

3 Results

It turns out that no change of the survival enzyme activity was found after irradiation through a thick foil.

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