

RESEARCH ON DENSE PLASMA FOCUS HARD X-RAY EMISSION WITH SCINTILLATOR-PHOTOMULTIPLIER AND THERMOLUMINISCENT DETECTORS MEASUREMENTS

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Abstract

The dense plasma focus (DPF) device, produces intense hard, soft X-ray and neutron bursts from a magnetically heated dense plasma. The purpose of the present work is to evaluate the intensity of hard X-rays from a plasma focus measured as a function of position, time and energy of emission. The high energy X-rays (energy ≥ 20 keV) come from a small region of the anode surface on the axis. They are detected with two methods: thermoluminescent dosimeters (TLDs) and scintillator-photomultiplier detector. The hard X-ray pulse typically rises in 3 ns, and frequently has a pulse width of 50 ns. The TLDs of $\text{CaF}_2:\text{Dy}$ (TLD-200) were used as detectors for absolute brightness measurements of X-ray emission from a DPF and comparison with measurements of scintillator (NE-102)-PM detector. This device would be used as an ultra fast and intense flash X-ray source for study of biological specimens.

1. Introduction

The plasma focus phenomenon was extensively studied from the early 70's and extensive literature was produced on it [1-4]. The most accepted hypothesis on the mechanism for which short pulses of hard X-ray are emitted from the focus [5,6] are described in the following. The $m = 0$ instabilities in the pinch produce an spatial charge separation with creation of intense electric field. This field generates positive ion beams ejected towards the gun front and also a corresponding high energy electron beam towards the anode. The impact of the electron beams on the anode metallic surface generates hard X-ray pulses (of hundreds of keV) with a duration of tens of nanoseconds. Also, soft X-ray (of some keV) are emitted from the thermal bulk of plasma when the compression in the pinch results effective and a main plasma temperature of some keV is achieved.

In this work we show the results of an experimental study of this hard X-ray emission in a small plasma focus device, using different diagnostic methods, and the performance of this radiation for use biological radioscopy.

2. Experimental devices and methods

We used the plasma focus PACO [7] of 2 kJ, 31 kV and 250 kA in the focus. In this work we use deuterium at 1.5 mb as filling gas because we were simultaneously researching the nuclear fusion D-D reactions, whose results are reported in other paper [8].

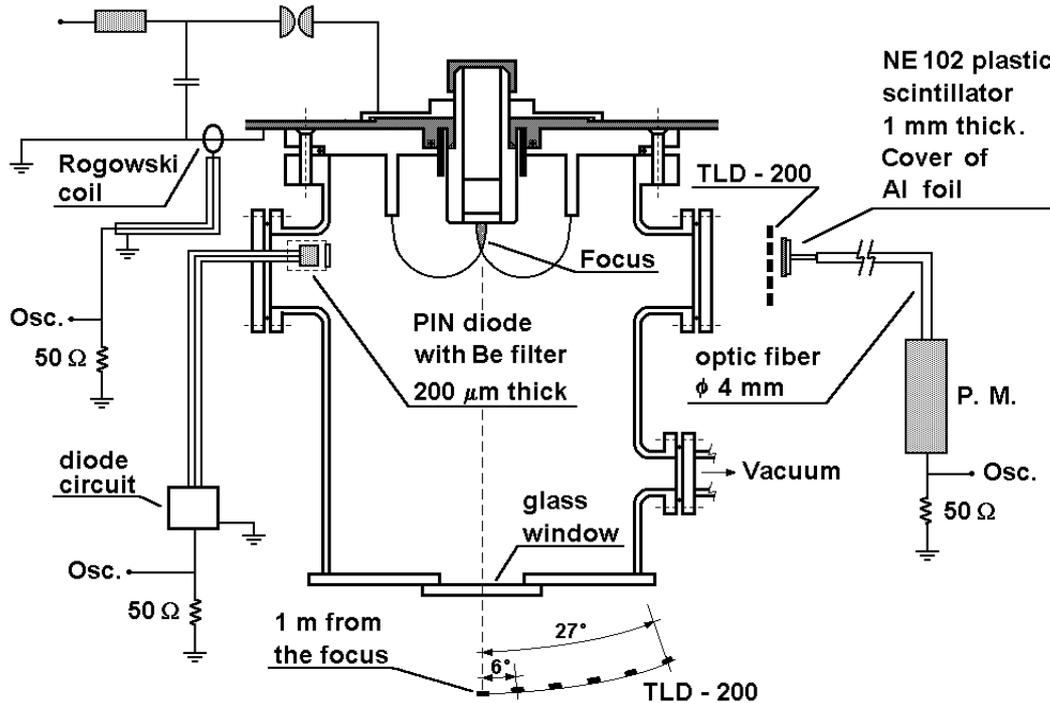


Figure 1. Experimental arrangement.

In Fig. 1 we show the scheme of the complete experimental arrangement. With the Rogowski coil we measure the derivative of the total current and the dip produced in its signal when the shot gives an effective pinch compression. The time-resolved X-ray emission is registered by two types of detectors: A PIN diode detector with a rise-time of some nanosecond, covered with a Be window 200 μm thick (in order to stop the visible light), that detects only the soft X-rays produced in the plasma bulk of a temperature of some keV, but is not sensitive to the hard X-ray emission. Into the purpose of this work, the measurements of this detector is only used in order to have an extra-information about the efficiency of the pinch compression. The second temporal detector is a plastic scintillator-photomultiplier system (PS-PM), specially made for detection of hard X-rays. The thickness of the NE102 plastic scintillator is 1 mm in order to minimize the interaction of neutrons emitted in the focus fusion reactions. This detector is located outside the discharge chamber, in front of a 5 mm glass window which represent an X-ray filter with an energy threshold of 20 keV. Using other filters, we determined that the X-ray energy has a maximum of about 300 keV. Thermoluminescent detector crystals of $\text{CaF}_2:\text{Dy}$ (TLD-200) [9] were used for integrated-time

measurement of X-ray energy dose. These detectors have a series of advantages, such as its sensitivity to a very broad spectrum of radiation ranging from 5 keV to a few MeV, they are not perturbed by electromagnetic flux variations, and they can have an absolute calibration in a very easy way. We used well-calibrated TLD-200 detectors, and measured the doses from the amplitude of the light intensity vs temperature curve, obtained in the developing process of radiated crystals. The PS-PM detector gives a voltage peak registered in a digital Tektronix TDS 540 oscilloscope and, from the amplitude of this peak, we obtain a measurement of the radiation intensity. The TLD development is a relative long process which needs several hours for obtain the numerical values of radiation dose. Instead, the PS-PM system gives an instantaneous measurement of X ray intensity, correlated with the dose. In order to know the correlation between the oscillogram peak of PS-PM and the corresponding dose measured with TLD we make calibration curves obtained at 0° and at 90° (such a curve can be seen in Fig. 2).

As it can be observed, the response is approximately linear and then, allows us to know, immediately and with good approximation, the dose value each shot in the position of calibration.

3. Results

In Fig. 3, we show the radiation dose distribution in different angles from the axis at 1 m in front of the focus (see also Fig. 1). As it can be seen, the dose is practically uniform in a cone of 10° around the axis corresponding to the angle subtended for the glass window. Instead, the dose results very low outside this zone where the X-ray must come through the 1 cm-thick iron flange. At 1 m this cone of uniform radiation corresponds to a circular surface of 20 cm in diameter.

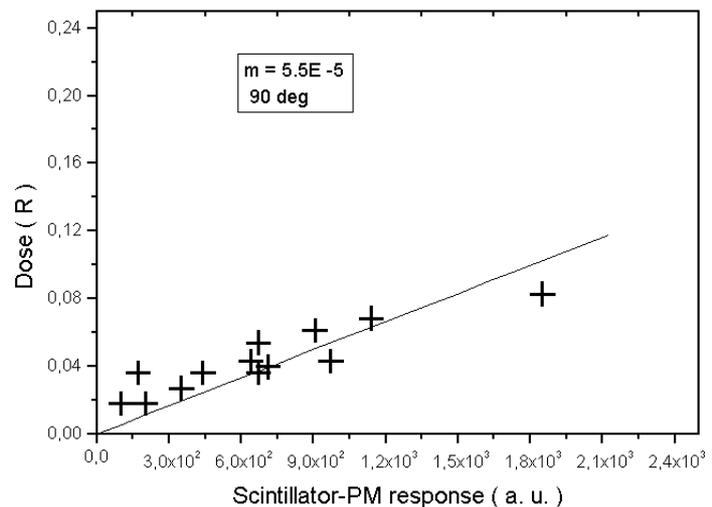


Figure 2. Calibration graphic of dose measured with TLD 200 vs. peak amplitude of scintillator-PM detector.

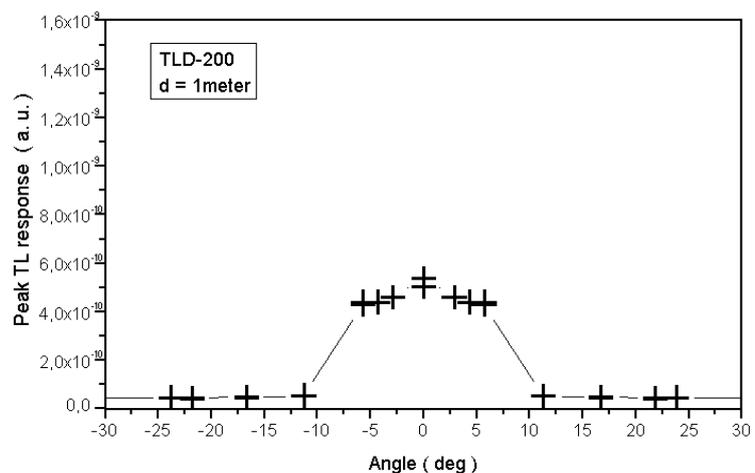


Figure 3. X-ray dose measured with TLD as function of the angle, as it is shown in Figure 1.

Finally, in Fig. 4 we show the radiography of a mouse taken in one shot (10 ns exposure-time) in this zone of uniform radiation. The white small circle inside the picture corresponds to the image of an iron cylinder of 1 cm of diameter and 1 cm high. The dose in this picture is about 200 mrad and the details observed give the idea that the X-ray source is very small (of the order of 0.1 mm or less). This is promissory fact for the use in microradiographies. Other relevant advantage is that the short exposure time allows to obtain radiographies of living animals, biological fluids incirculation, etc.



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Figure 4. X-ray picture of a mouse obtained in a single shot of PACO (10 ns x-pulse), at 1 m in front the focus.

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