STUDIES ON X-RAY AND NEUTRON EMISSION FROM 2.2 KJ PLASMA FOCUS DEVICE

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Plasma focus (PF) is a rich source of pulse X-ray and neutron emission. The measurement and analysis of X-ray and neutron emission from a 2.2 kJ PF device has been carried out using photo multiplier tube (PMT), PIN diode, pinhole camera, vacuum photodiode (VPD) and neutron bubble dosimeter. The soft X-rays are more or less emitted in multiple pulses. Hot spots are found to be present in the X-ray emitting zones of pinched plasma column. The neutron emissions are more in numbers as well as more energetic in axial direction as compared to the radial one. The neutron's anisotropic emission may be influenced by beam- target mechanism.

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INTRODUCTION

Plasma focus has been able to draw the attention of researchers as source of various emissions since its inception. The plasma produced in the device offers the researchers an avenue to study the wide range of phenomena like instability generation [1,2], turbulence formation [3], electromagnetic and energetic particle emission in highly dense transient pinched plasma. Thus, the pinched plasma produced in plasma focus device has found wide varieties of applications as source of X-rays, neutrons, ions, electrons [4,5] and researchers are attempting to miniaturize the device day by day so as to make it more compact and handy [6]. On the other hand, Lee et al. [7] used the PF as a tool to demonstrate plasma phenomena to the masters' students. In addition to this the basic studies on the pinch formation and its emission process is also going on simultaneously [8]. We have attempted to carry out a study on the behaviour of X-ray and neutron emissions in our PF device.

1. EXPERIMENTAL SET UP

The experiment was carried out in a 2.2 kJ Mather type PF device, which consists of a coaxial electrode assembly. The schematic of the experimental system is shown in Fig. 1. The system was energized by a high voltage energy storage capacitor (7.1 µF, 40 kV). The detailed electrical and mechanical parameters of the device are reported elsewhere in [9]. The whole electrode assembly was housed inside an SS vacuum chamber having approximate volume of 6 liters. The chamber is filled with deuterium gas and evacuated up to desired pressure level by using a rotary pump. The chamber pressure was monitored using a McLeod gauge. In the present experiment, we have employed VPD, PIN diode (BPX-65) to record time resolved soft X-ray signal in digital storage oscilloscope [DL 9240 of Yokogawa]. The soft X-ray image of the plasma column was recorded in film [Dental X-ray film] using pinhole camera. To measure hard X-ray and neutrons, we have employed plastic scintillator (RP400) combined PMT [9813QB of Electron Tube Inc.] and bubble dosimeter (BD-PND) in axial and radial position of PF.

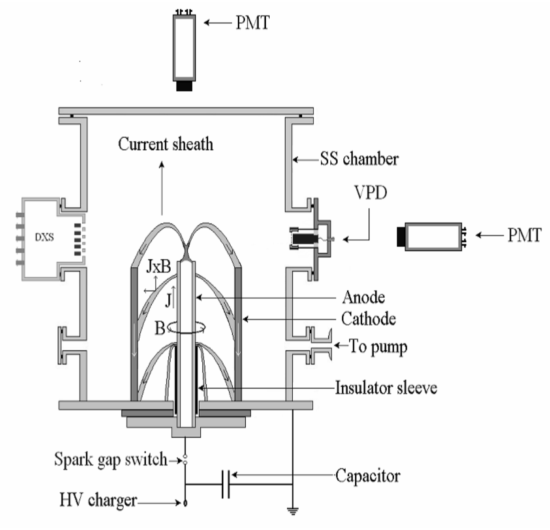
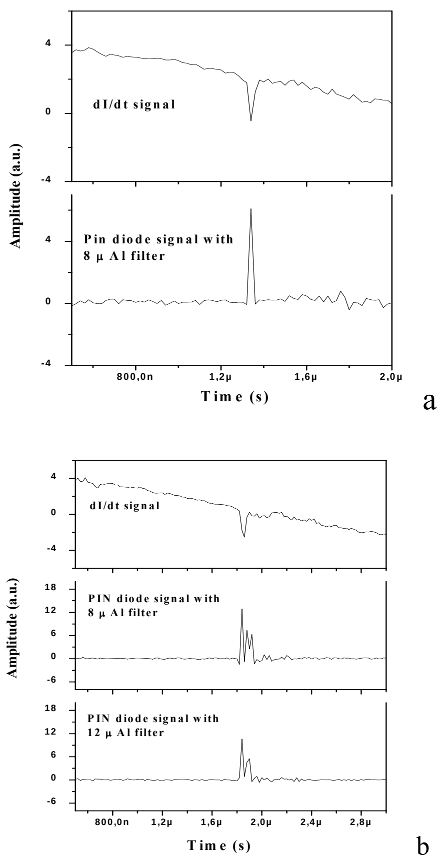


Fig. 1. Schematic of PF device with diagnostics

2. RESULTS AND DISCUSSION

The optimized operating pressure for soft X-ray emission is found to be 1 Torr. The time resolved soft X-ray pulses were detected by using PIN diodes with the corresponding *dI/dt* signal of Rogowski coil (Fig. 2,a). It is seen that the X-ray pulses are emitting just at the moment of maximum compression (dip in the *dI/dt* signal) as it is found that the *dI/dt* and peak of the X-ray signal matches each other and its duration is comparable to the lifetime of the *dI/dt* dip. This type of X-ray pulse is emitted by the Bremsstrahlung radiation of electrons in the strongly compressed plasma column. In few PF shots, the soft X-ray emission comes out in multiple pulses (Fig. 2,b). The intensity of second and third pulse is always lower than the first pulse. The second and third X-ray pulses might be generated by a recompressed plasma [10] or hot spots forming after the first compression.



a

b

Fig. 2. Typical X-ray signal with dI/dt signal detected by by using PIN diode (a) soft X-ray single pulse (b) soft X-ray multiple pulses

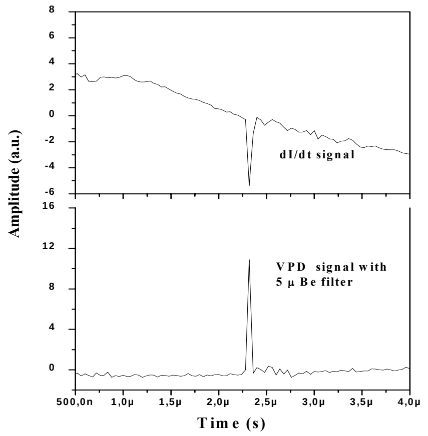
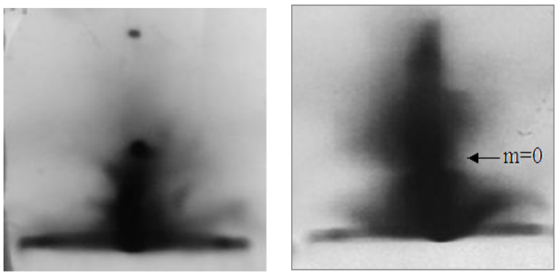


Fig. 3. Typical VPD signal with dI/dt signal

The electron temperature of the pinched plasma can be measured using intensity ratio technique of two PIN diode channels. In our case we used two PIN diode of DXS with 8 and 12 µm Al filters and averaged for X-ray signals of five different PF shots. The estimated electron temperature is found to be 1.25 keV.

One can even use a suitably designed VPD to see the temporal evolution of soft X-ray emission from PF device [Fig. 3]. The VPD is a simple, cost effective and robust diagnostics and we have already used it to measure average energy soft X-ray emitting pulse [11]. The VPD signal shown in the figure [Fig. 3] is comparable to PIN diode signals (see Fig. 2,a).



a b

Fig. 4. Image of pinched column of PF device (a) hotspots formation (b) m=0 instability

The size and shape of the pinched plasma column were determined from the pinhole camera image. The typical length and diameter of pinched plasma column is found to be around 10 mm and 2 mm respectively. Hot spots are regularly observed in the compressed plasma column (Fig. 4) and in some cases the hot spots are found to be formed in a region not surrounded by plasma (see Fig. 4,a). Hot spots formation is a regular phenomenon in PF [12] and even the distant hotspots forming away from plasma is also not new [13]. These distant hot spots may be formed due to interaction of trapped ions in the magnetic field with the rarefied plasma away from main compressed region. It is established that the breaking of pinched column mainly started due to necking in the column (m = 0 type instability) (see Fig. 4,b).

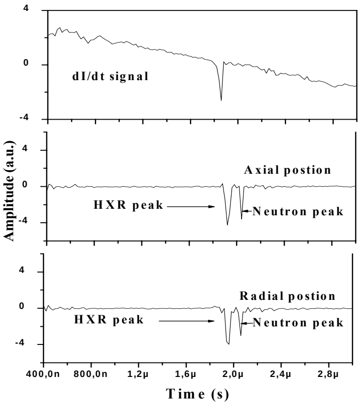


Fig. 5. Typical Hard X-ray and neutron signal with dI/dt signal

The temporal evolution of neutron emissions is observed putting two PMTs combined with scintilator [RP400] at distance 2 m away from the plasma column in axial and radial direction of the source. It is observed that the axial neutron pulse is coming out earlier [110 ns] than its radial counterpart [120 ns] (Fig. 5). This suggests that the axial neutrons are having more kinetic energy as compared to the radial one. Similarly numbers of neutron emitting in the axial direction are found to be more as compared to the radial one as the arbitrary intensity of axial neutron pulse found to be higher than the radial counterpart in same experimental condition (see Fig. 5). This is further confirmed from bubble dosimeter as we have observed more numbers of bubble formations in the dosimeter [BD-PND] in the axial direction as compared to the radial direction. The details of our neutron studies will be reported later. However the present results are sufficient to indicate that some agent is responsible to increase the energy and numbers of neutron in the axial direction. This suggests that the mechanism like beam-target interaction might have active role in the PF neutron [14] generation in our case also.

CONCLUSIONS

The present work is part of our continuous effort to understand X-ray and neutron emission from PF device. Here we have presented few diagnostics for X-ray and neutron emission from PF and attempted to explain the generation of multiple X- pulses and hot spot formation. There is further scope to carryout these studies with theoretical work and to find out the possible correlation X-ray pulses and hot spots formation with corresponding neutron emission.

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ИССЛЕДОВАНИЕ РЕНТГЕНОВСКОГО И НЕЙТРОННОГО ИЗЛУЧЕНИЯ ИЗ 2,2 кДж ПЛАЗМЕННОГО ФОКУСА

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Плазменный фокус (ПФ) является источником импульсов рентгеновского и нейтронного излучениий. Были проведены измерения и анализ рентгеновского и нейтронного излучений из 2.2 кДж плазменного фокуса с использованием фотоумножителя (ФЭУ), PIN-диодов, камеры-обскуры, вакуумного фотодиода и пузырькового дозиметра нейтронов. Мягкое рентгеновское излучение более или менее наблюдается в импульсах со сложной структурой. Горячие точки были обнаружены в зонах рентгеновского излучения в сжимающемся плазменном шнуре. Нейтронное излучение в разы больше и энергетичнее в осевом направлении по сравнению с радиальным. Анизотропное нейтронное излучение может зависеть от механизма взаимодействия пучка с мишенью.

ДОСЛІДЖЕННЯ РЕНТГЕНІВСЬКОГО І НЕЙТРОННОГО ВИПРОМІНЮВАННЯ З 2,2 кДж ПЛАЗМОВОГО ФОКУСА

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Плазмовий фокус (ПФ) є джерелом імпульсів рентгенівського і нейтронного випромінювань. Були проведені вимірювання і аналіз рентгенівського і нейтронного випромінювань з 2.2 кДж плазмового фокуса з використанням фотопомножувача (ФЕП), PIN-діодів, камери-обскури, вакуумного фотодіода і бульбашкового дозиметру нейтронів. М'яке рентгенівське випромінювання більш-менш спостерігається в імпульсах зі складною структурою. Гарячі точки були виявлені в зонах рентгенівського випромінювання, що стискаються в плазмовому шнурі. Нейтронне випромінювання в рази більше і енергетичніше в осьовому напрямку в порівнянні з радіальним. Анізотропне нейтронне випромінювання може залежати від механізму взаємодії пучка з мішенню.