academicJournals

Vol. 8(8), pp. 286-294, 28 February, 2013
DOI: 10.5897/IJPS12.552
ISSN 1992-1950 ©2013 Academic Journals
http://www.academicjournals.org/IJPS

International Journal of Physical Sciences

Full Length Research Paper

The impact of plasma interference profile (PIP) on argon discharge in plasma focus device

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Accepted 22 February, 2013

Radiation emission in a low energy (2.2 kJ, 12 kV) UM plasma focus is studied. The system is operated in Argon filling gas. Enrichment of the radiation emission yield is obtained with an optimized pressure 1.7 mbar. Time resolved radiation emission measurements are made by using an array of PIN diode detectors covered with few Al foil thicknesses, to be found at top arrangement at distance 43.50 cm from the edged-surface of hollow anode (18 cm length/1.9 cm diameter). A notable increase of radiation yield is achieved at 1.7 mbar, which is about 0.00253 mJ with efficiency of 0.00012%, and also a pragmatic consequence of ionized gas particles so-called plasma interference profile impact on the radiation emission taken as a whole. The findings may exceedingly take part in a foundation of potential applications of the electron beam emission from plasma focus (PF) device.

Key words: Dense plasma focus, UM plasma focus, radiation emission, x-ray yields, argon plasma, electron beam, plasma interference profile (PIP).

INTRODUCTION

The plasma interference profile (PIP) may be define as “the radiation emits from the focus region and electron beam interaction with any shape of anode that pass through a ionized gas particles thin layer, the radiation intensity may maximize or minimize in a very short interval, up to foils”. With this pragmatic idea of plasma interference profile, which play a significance role in the measurement of radiation intensities within plasma focus devices same like other parameters, for instance, shapes of anode cylindrical, cone, tapered etc. The effects of anode shape (Zakaullah et al., 2000a; Muhammadi et al., 2009; Habibi et al., 2010; Aghmir and Behbahani, 2011), length (Neog et al., 2006; Mohammadi et al., 2007), material (Zakaullah et al., 1997) on the radiation emission yield (Khan et al., 2013; Moo and Wong, 1995; Akel and Lee 2012; Hussain et al., 2007) from the low energy Mather-type plasma focus device (Lee and Saw, 2008; Mather, 1965) with different gases, for instance, Argon, Neon, Nitrogen or sometime mixture of gases of optimized pressure. The study of neutron emission (Yap et al., 2005; Verma et al., 2008); electron beam emission (Choi et al., 1990; Patran et al., 2005) and high energy ion beam emission (Wong et al., 2002; Shahbazirad et al., 2011) from the plasma focus devices are continuing in different focus laboratories in the World. Researchers mostly considered the effects of anode shape, length and material of anode but they never see some ionized gas particle may also carrying out essential character on the

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reduction of real yield of radiation emission from the plasma focus devices on the whole. It is considered to be an important consequence offer the radiation intensity scope in the plasma focus system. The interference of that ionized gas particles layer so-called plasma interference profile (PIP) has a proficient role to reduce the real yield of radiation which may perhaps be achieved through plasma focus devices.

Method of plasma generation is based on the passage of electron beams through gas, an pragmatic idea comes to play role that introduction of small particles and clusters into weakly ionized gas can change its electrical properties because of particle can absorb charge particles mean electrons and ions may combine on these particles by attachment to them. It is occurring in Aerosol plasma. If this process is happening inside the plasma focus chamber, then ionized particle thin layer may play very important role in front of radiation emission from focus region as well as hitting of electron beam with anode surface, which is so-called PIP.

In chronological surroundings, two waves superimpose to form a resultant wave of greater or lower amplitude is called Interference. Usually, it refers to the interaction of waves, which may be coherent with each other, from same source or they have nearly same frequency. Interference impact may be observed more or less all types of waves, for instance, light, radio, acoustic, surface water waves etc. On bases of above circumstances, within plasma, compression waves are called longitudinal waves. All types of electromagnetic radiation (EMR) are experimentally found to be move at close to the speed of light in vacuum. Classical physics concept, electrons are main source for emission of most EMR due to low mass and easily accelerated by a number of mechanisms. The highest frequency of EMR observed in nature due to most sharply accelerated electrons encounter a region of force. Quantum mechanics (QM) concept, all particles behaves particle and wave properties in nature; this duality addresses the instability of classical concepts. It is true; QM does not yield a description of an objective reality but deals only with possibilities of observing or measuring various aspects of energy quanta, which fit neither the classical idea of particle nor the classical idea of waves. It is the only way to directly and arbitrarily assume of possible values because of the set of probabilities. The standard model (SM) of particle physics (http://www-sldnt.slac.stanford.edu/alr/standard_model.htm) provides a stage for explaining chemistry and nuclear physics, particularly, low energy processes. Photons have certain symmetry at every point in space-time regarding necessary consequence of physical laws. According to properties of gauge symmetry, the charge, mass and spin are the intrinsic properties of photons. That information about photons, has led to vital advances in experimental and theoretical physics, such as lasers, Bose-Einstein condensation, quantum field theory (QFT), and probabilistic interpretation of QM. Recently, photons have been studied as elements of quantum computer and for dense applications in optical communication such as quantum cryptography.

In this paper, first time, we report the new effect on modified University of Malaya Plasma Focus Device (UM-PF) radiation emission when the pragmatic presence of PIP may near at the top arrangement in front of detector and also find out the radiation emission yield with efficiency. Our attempt may help to tailored the UM plasma focus device as an exceptional radiation emission source for the prospect study of electron beam emission, which may be use for potential hi-tech application.

EXPERIMENTAL DETAILS

The series of experiments were carried out on the Mather-type plasma focus (PF) device located at the Plasma Technology Research Center University of Malaya Kuala Lumpur. The PF device is energized by a signal 30 µF Maxwell capacitor charged up to 12 kV. The calculated total external inductance is 165 nH. The schematic and graphic of 2.2 kJ PF device and the five channel BPX65 PIN diode spectrometer are shown in Figures 1 and 2. The discharge tube consists of an inner electrode, which is made of hollow copper pipe (of 1.9 cm diameter / 18 cm length). The photo of plasma focus device and outer electrode is as a group of six copper rods which form the shape of a squirrel cage with an inner diameter of 3.2 cm is shown in Figure 3. Hollow anode and cathode are separated by a Pyrex glass insulator (5 cm length). The component specification of the plasma focus device is given in Table 1. A rotary van pump is used, which evacuates the chamber to lower than 10^{-2} mbar before puffing Argon gas. As the gas contamination with impurities have a considerable effect on output radiation, the chamber is refreshed after every five shot and fresh Argon gas is refilled to the mainly required pressures.

Five identical coaxial cables of length 110 cm were used for five channels BPX65 PIN diode spectrometer, while coaxial cables of length 310 cm for Rogowski coil and high voltage probe to detect at oscilloscope. All coaxial cables are shielded with aluminum foils during experiments to reduce the effects of electromagnetic noises on data signals. All the electrical signals from the Rogowski coil, high voltage probe and the five channels PIN diode's signal are recorded by two DPO 4043 digital storage oscilloscope. Digital oscilloscope was triggered simultaneously for all signals. An array of five channels PIN diode (BPX65) housed at 43.50 cm far from the edged surface of hollow anode head were used to measure the radiation emission from focused plasma. For X-ray detection the glass windows of the PIN diodes were detached. The windows were covered with Aluminum foils which the thickness of each of them is given in Table 1. The peak current and system inductance can be computed using equations (Lee, 1983).

$$I_0 = \frac{\pi C_o V_o (1+f)}{T} \tag{1}$$

$$L_o = \frac{T^2}{4\pi^2 C_o} \tag{2}$$

For the detection of X-ray, an array of five filtered PIN photodiodes (BPX-65) housed at 43.50 cm far from the hollow anode head were used to measure the radiation emission from focused plasma. For X-ray detection the glass windows of the PIN diodes were detached. The PIN diodes response is between 0.5 and 30 keV

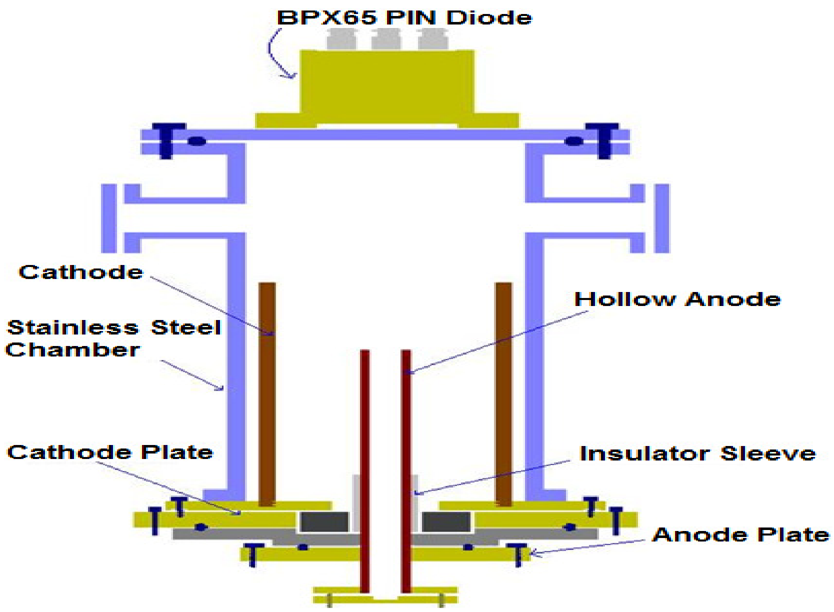

Figure 1. Schematics of UM plasma focus device.

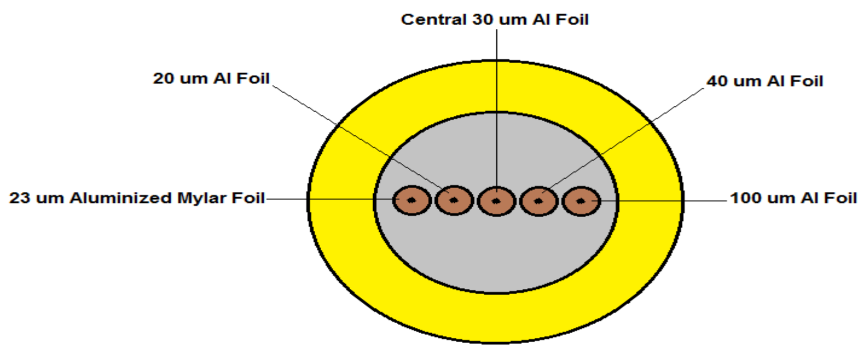

Figure 2. Five channels BPX65 PIN diode with masked Al foils positions.

(Zakaullah et al., 2000b). The windows were covered with Al foils which the thickness of each of them was given in Table 2.

The fundamental circuit of the BPX65 diode is shown in Figure 4 and it is reverse biased at -45 Volts. The transmission curves of the BPX65 PIN diode along with their attached absorption filters are presented in Figure 5. Spectral analysis is conducted by using Ross-filters (Johnson, 1974) set of Al (with different thickness) together with the PIN diodes x-ray spectrometer. To estimate the contribution of X-ray, the selected Ross-filters set is composed of two thickness of Al foil. The difference between the signal intensities (area under the curve) of the detectors which are masked separately with Al foils, provide the X-ray in the energy range ~ keV. The Al foils masking the five channel PIN diodes X-ray spectrometer may help to estimate the X-ray yield in 4π-geometry, and the system efficiency for X-ray generation. Energy radiated as X-rays is determined by formula (Khan et al., 2013).

$$Y = \frac{Q_{\exp}(4\pi)}{d\Omega S(E) T(E)} \quad (3)$$

Where, $Q_{exp} = \int \frac{Vdt}{R}$ (C), $\int Vdt$ = area under the signals with five channel BPX65 PIN diode's filters, S (E) = average sensitivity of the detector, T (E) = average transmission of the filter, R = 50 Ω, in our experiments, $d\Omega = da/r_o^2$ (sr.) is the solid angle subtended by the detector at the center of the anode, Where, $da = \pi r^2$,r = 0.4 cm, is the radius of the exposed area of each detector and r_o = 43.50 cm, is the distance from the detector to the center of the hollow anode.

RESULTS AND DISCUSSION

The X-ray emission from the plasma focus operated with Argon is investigated by time resolved pin diode detectors(five channel BPX65 PIN diode). It is found that the average signal intensity recorded by five channel BPX65 PIN diode spectrometer attains its maximum value at 1.7 mbar Argon gas pressure.

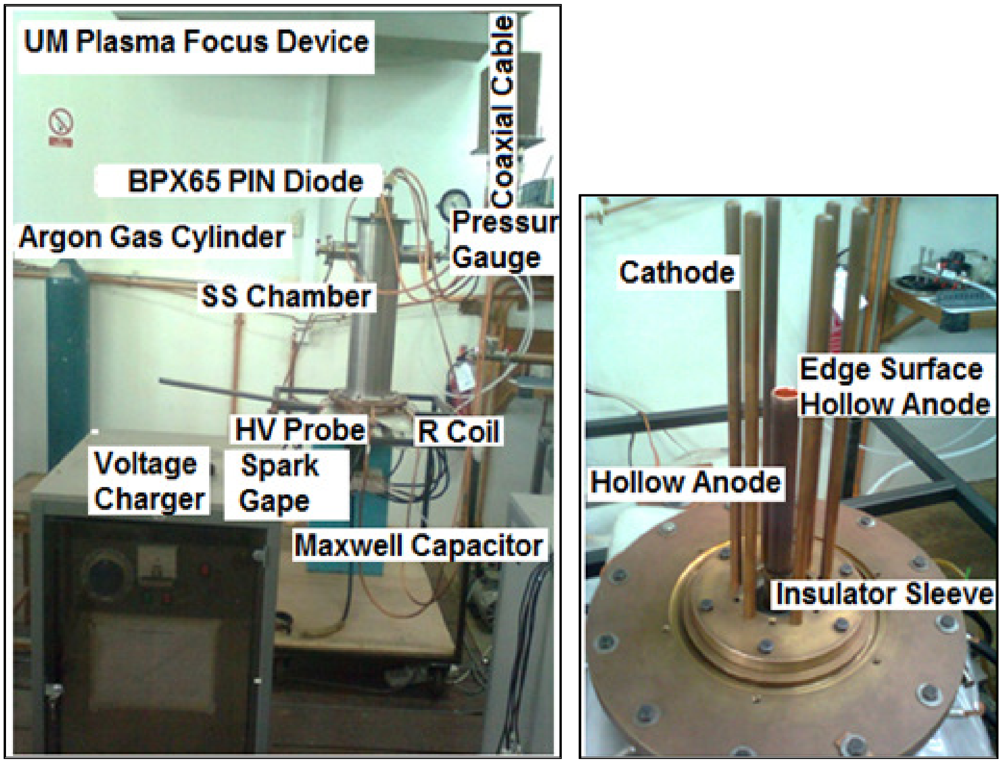

Figure 3. Inner Hollow Anode and Outer Cathode arrangement (a); UM-PF system (b).

Table 1. The components with applied specification of UM-PF device.

Component	Diameter (cm)	Length (cm)	Material
Vacuum chamber	14.25 (O.D) / 14.50 (I.D)	61.50	Stainless steel
Hollow anode	1.90 / 1.60 (O.D/I.D)	18.00	Copper
Cathode rod	0.95	27.20	Copper
Insulator sleeve	2.00	5.00	Pyrex

Table 2. A selection of five PIN diodes covered with Al foils + Aluminized Mylar (µm).

No. of PIN diode	Foils	Thickness (µm)
1	Aluminized Mylar	23
2	Aluminized Mylar + Al	23 + 20
3	Aluminized Mylar + Al	23 + 30
4	Aluminized Mylar + Al	23 + 40
5	Aluminized Mylar + Al	23 + 100

The total discharge current and voltage was measured by a Rogowski coil and high voltage probe respectively. The typical signal of Rogowski coil and high voltage probe is shown in Figure 6. The variation of X-ray emission as a function of Argon filling pressure can play effective role in generation of radiation in UM-PF device (Table 3). The variation of average signal intensity with the pressure of Argon filling gas is described in Figure 7. Figure 8 shows the variation of total X-ray yield and efficiency against the Argon gas pressure with constant

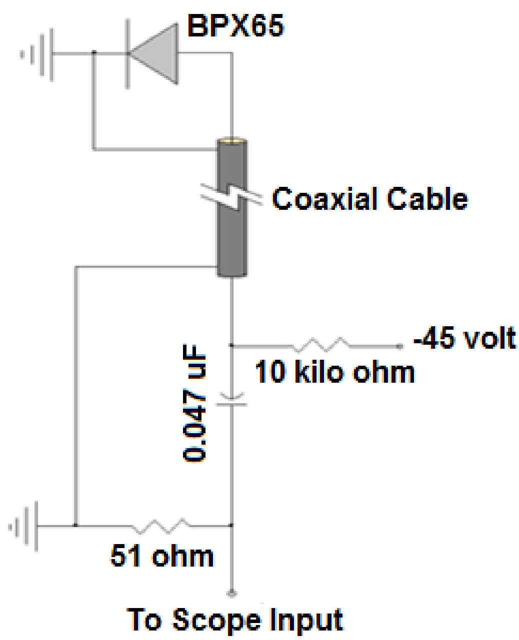

Figure 4. The fundamental circuit of the BPX65 PIN photodiode.

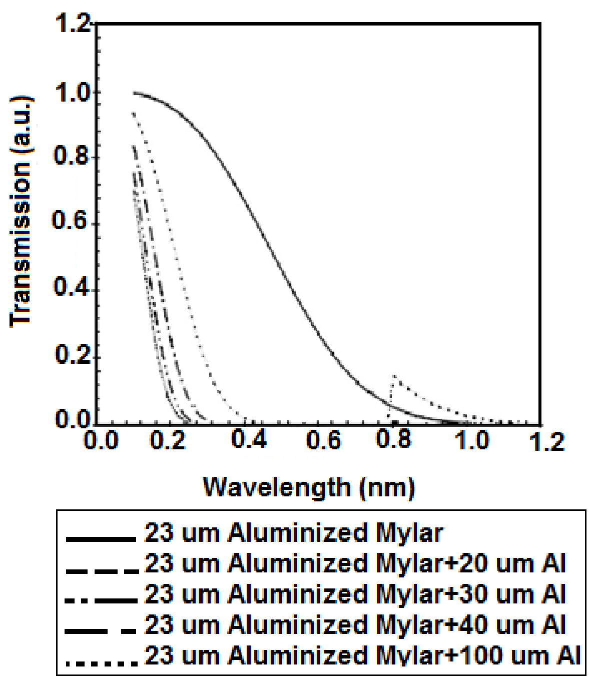

Figure 5. Transmission curves of Aluminized Mylar (23 µm), [Aluminized Mylar (23 µm) + Al foil (20 µm, 30 µm, 40 µm, 100 µm)].

Table 3. System specification and experimental results at optimum condition of UM-PF device.

Parameter	Symbol and unit	Specification
Charging voltage	V_o (kV)	12
Capacitance	C_o (µF)	30
Stored energy	E (J)	2160
Inductance	L_o (nH)	165
Impedance	Z_o (mΩ)	74
Peak current discharge	I_o (kA)	140
Resistance of electric circuit	R_o (mΩ)	14

12 kV voltage. Maximum X-ray yield and efficiency in 4π-geometry for optimized pressure 1.7 mbar with constant voltage 12 kV are given in Table 4. After a series of experiments, we got optimized pressure 1.7 mbar at constant voltage 12 kV by using the five channels PBX65 PIN diode masked with different thickness of Aluminium foils (Table 2). Our concentration is on three filters which are exactly on the top of hollow anode tip at distance 43.50 cm. In case of 18 cm long hollow anode, electron beam from the focus region will interact very less edged-surface of hollow anode, so radiation emit from focus and after hitting with the edged-surface of hollow anode is pass through the different thickness foils of aluminium with 23 µm aluminized Mylar is used. The total X-ray yield from 30 µm Al + 23 µm Aluminized Mylar is found 0.00083 mJ with efficiency 0.00004%, which is less as compared to total X-ray yield from 20 µm Al + 23 µm Aluminized Mylar (0.00253 mJ) and 40 µm Al + 23 µm Aluminized Mylar (0.00182 mJ) with efficiency 0.00012 and 0.00009% respectively.

It is exceedingly appealing result that is never reported in PF devices up to our knowledge, the Al foils position are shown in Figure 1. The 30 µm Al + 23 µm Aluminized Mylar is at exactly at centre of five channel BPX65 PIN diode and others two PIN diodes (20 and 40 µm with 23 µm Aluminized Mylar) in first circle and further two PIN diode (23 µm Aluminized Mylar and 100 µm Al foil with 23 µm Aluminized Mylar) in second circle, are of this central foil. So, radiation is less proficient to advance this foil thickness as compared to the first circle PIN diodes because of electron beam interact with edged-surface of hollow anode and centrally electron beam hits bottom of anode which is surely not possible to get approach to the central Al foil 30 µm of five channel BPX65 PIN diode, while most feasible on other foils (Al 20 µm and Al 40 µm) is due to the edged-surface interactions of hollow anode. At that time of focus, electron beam generate from the focus point and hit with the hollow anode edged-surface or from the bottom of the anode plate at the depth of 28 cm from the tip of hollow anode. A flux of radiation emit from the focus region and electron beam interaction with hollow anode edged-surface.

We can imagine what is happening inside the chamber as shown in Figure 9. At optimized pressure 1.7 mbar of Argon gas, which is scanned before performing present

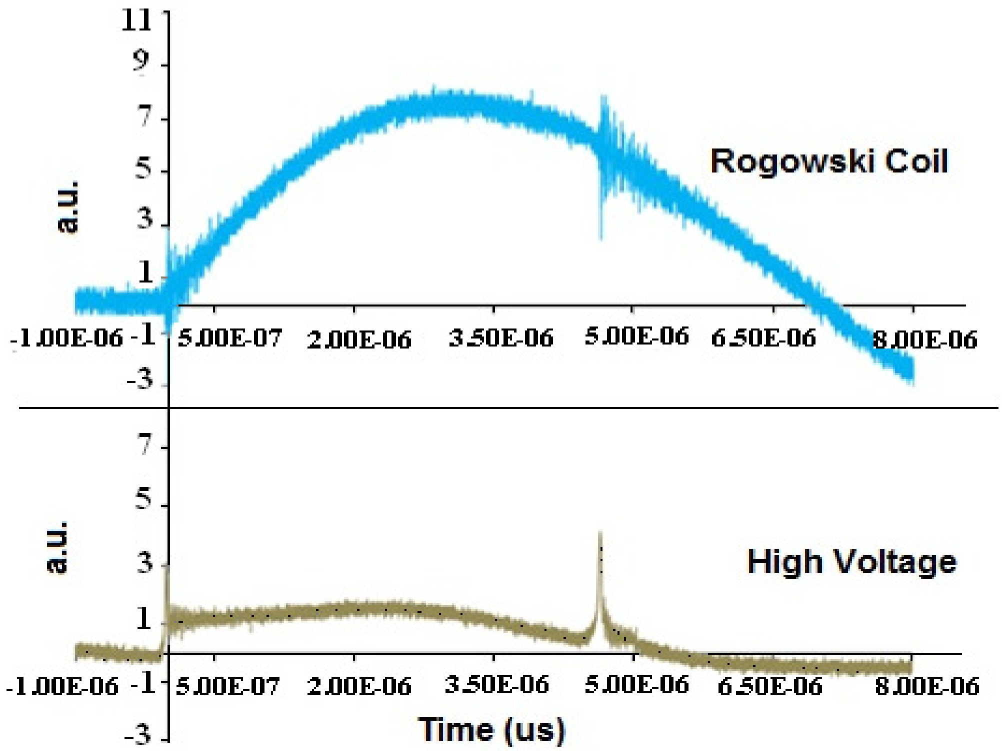

Figure 6. The typical signal of Rogowski coil and high voltage probe.

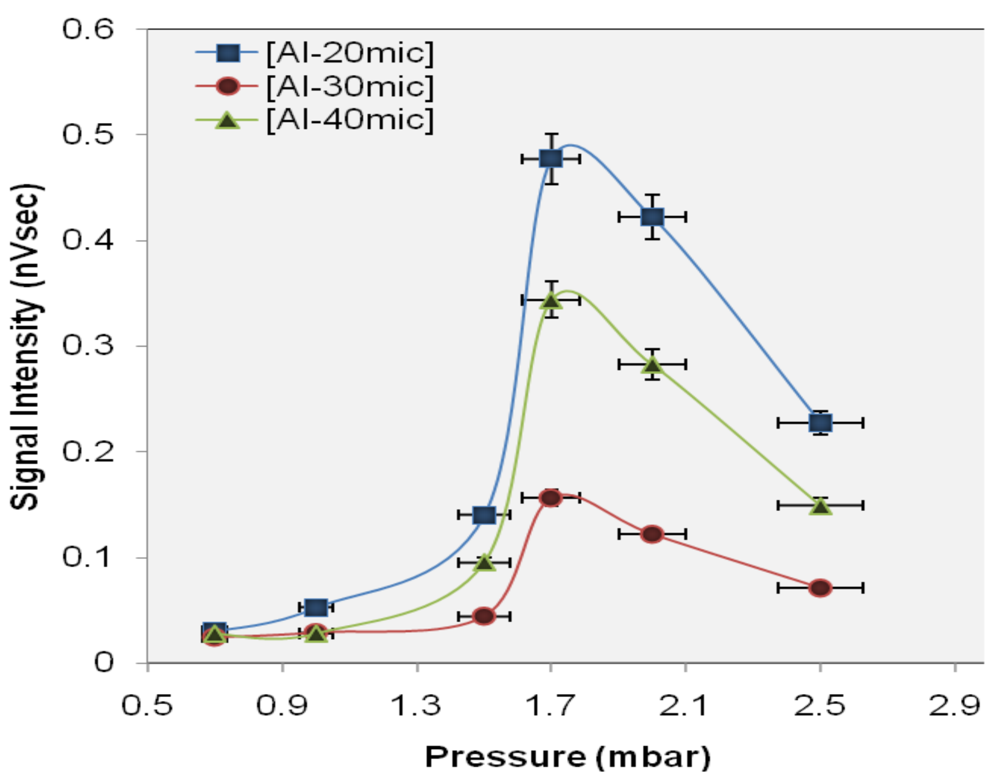

Figure 7. Variation of signal intensity recorded by Five Channel BPX 65 PIN diode with Al foils thickness versus argon gas pressure.

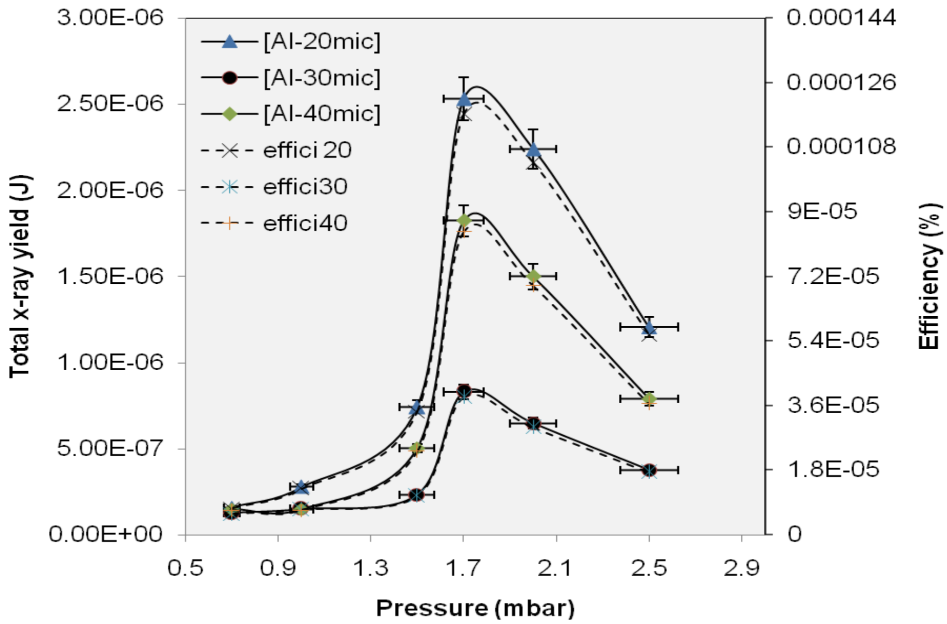

Figure 8. Variation of total x-ray yield in 4π-geometry and system efficiency versus argon gas pressure having constant voltage 12 kV.

Table 4. Total X-ray yield with Al foil plus 23µm Aluminized Mylar + Al foils with efficiency.

BPX65+Aluminium foils thickness	Total x-ray yield (mJ)	Efficiency (%)
20 µm Al + 23 µm Aluminized Mylar	0.00253	0.00012
30 µm Al + 23 µm Aluminized Mylar	0.00083	0.00004
40 µm Al + 23 µm Aluminized Mylar	0.00182	0.00009

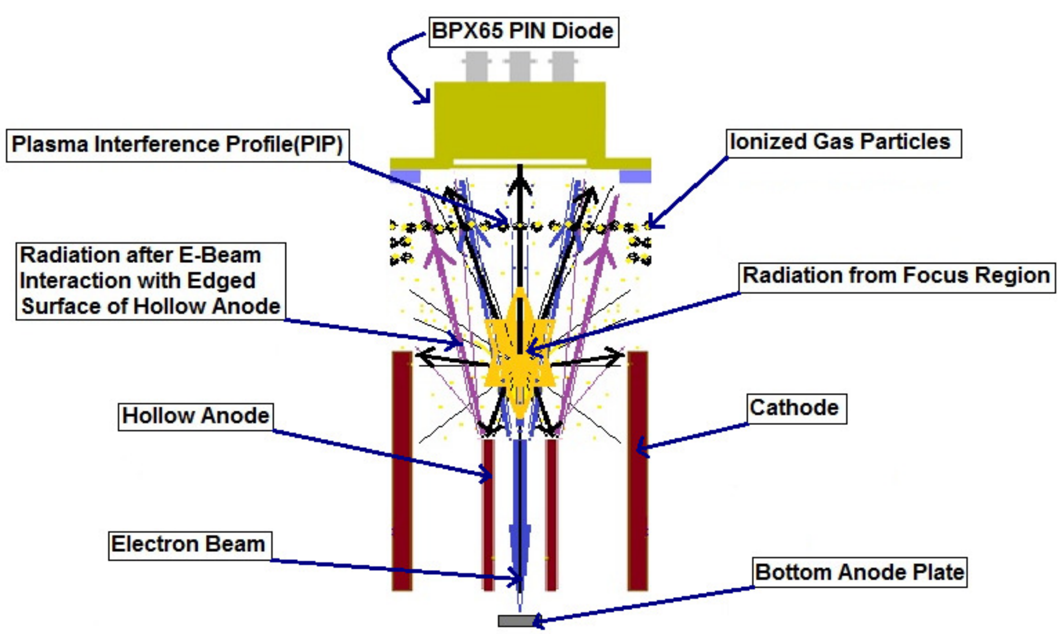

Figure 9. Pragmatic situation of release within the UM-PF chamber.

experiment. When plasma column compressed and breakup; electron beam, ion beam, and number of other radiation generate from the focus region. Ions are heavy particles as compared to the electron regarding masses, so electron interact with edged-surface of hollow anode and maximum hit at the bottom of the anode plate. It can be considered the electron beam interaction with hollow anode is extremely less as compared to the solid anodes with different shapes. So radiation collectively approaches at the PIN diode is placed at very far away distance 43.50 cm from the edged-surface of hollow anode. The Figure 7 shows that emission of radiation from plasma region and electron beam interaction with edged-surface of hollow anode/bottom of anode plate pass through the ionized gas particle layer “PIP”, intensity of radiation may diminish in yield which may expect to determine through different thickness of Al foils are used. The reduction of radiation intensity is seen clearly in hollow anode case but in different shape of anode, for instance, cylindrical, conical, tapered is not seen because electron beam interaction with surface of solid anode is most as compared to the hollow anode (Zakaullah et al., 2001). Therefore, this effect is more prominent in case of hollow anode. It means we can enhance the radiation intensity with the same parameters, are used in different plasma focus devices.

Comparatively, we may conclude that PIP play significance role on the radiation intensity in hollow anode as well as in solid anode case. It plays same role on the surface of solid anode but we are not able to judge this effect on the radiation yield due to strong interaction of electron beam from the focus region. The results are presented with the Table 4. The maximum radiation intensity is 0.00253 and 0.00182 mJ within the first circle position and minimum radiation intensity is 0.00083 mJ at the central position of Al of foils with defined thickness in Table 2. It is found unexpected radiation emission intensity through Al foils.

If we assume that before/after focus, ionized gas particles may increase in number within the chamber, which work as a thin layer so-called PIP to reduce the radiation emission intensity. If it happens within the chamber, then we may possibly lose a significant yield of radiation intensity due to PIP. We are also in the process of fine tuning the modified UM plasma focus device to generate the high electron beam intensity.

Conclusion

A low energy (2.2 kJ / 12 kV) UM plasma focus device is studied as radiation emission source with working gas Argon. PIN diode detectors covered with Al foil thicknesses at top display at distance 43.50 cm from the edged-surface of hollow anode is used for the determination of time resolved radiation emission yield. A prominent radiation emission yield is achieved at 1.7 mbar, which is about 0.00253 and 0.00182 mJ. The role of a pragmatic consequence of ionized gas particles so-called PIP within device may reduce the radiation emission taken as a whole, which is about 0.00083 mJ with efficiency 0.00004% at central position. The findings may be useful in percentage increase of radiation emanation amount in plasma focus devices and also groundwork of latent applications in future.

ACKNOWLEDGEMENTS

Muhammad Zubair Khan wishes to acknowledge Mr. Lim for arranging system setup and Mr. Jasbir Sing for the technical support. This project is supported by RG102-10AFR. Authors also wish to acknowledge the excellent support set by Federal Urdu University of Arts, Science and Technology (FUUAST) Islamabad Pakistan for continuing smooth study in University of Malay (UM) Kuala Lumpur Malaysia.

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