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A Study of Charged Particle Beams Emission from Argon Focus Plasma

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ABSTRACT

The aim of this work is to study and investigate the emission of charged particle beams from a plasma focus region. A plasma focus device employed in this work was a Mather-type [1] of storage energy in the range from 1 to 2.22kJ. This device was energized by (30.84µF) capacitor bank charged in the range from (8 to 12kV) giving a peak discharge current of 156.6KA with rise time » 3.5µSec.The discharge takes place in Argon gas and its pressure varied from 0.5 to 2torr.Charged particle beams included ion and electron beams emission from a plasma focus region and after the disruption of pinch column were detected by using a Faraday cup technique. The correlation of ion and electron beams intensity, energy and density with gas pressure and charging voltage was detected experimentally. The experimental results revealed, that the maximum values of ion beams and electron beams intensity was detected at V_{ch} =12kV and P=2torr.

Keywords : Plasma Focus / Faraday Cup / Charged Particle Beams

INTRODUCTION

The plasma focus devices are pulsed discharges producing a self generated magnetic field to pinch the plasma to a high dense and hot plasma column [2]. During the pinching a micro-instabilities and turbulence lead to a disruption of pinch column and then a generation of beams of ions and electrons are emitted [3,4]. Electron and ion beams emission from a plasma focus were investigated previously by many authors, some of them are reported here.

Styger et al [5] reported that, the electron beam energy distributed from 20 keV to 500 keV. They also found that the energy spectra electron beam obeyed to a power law $E^{\ 3.5\pm0.5}$. Bostick et al. [6] recorded that the ion pulses having pulse width (FWHM) 40-60ns using a Faraday cup (FC) technique. Rawat and Srira [7] demonstrated that, the fine structure of argon ion analysis from a low energy PF had a multi-spike structures of successive bursts of ions. Sadowski and Zebrowski [8] reported single peak or double peaks in electron beam signal that were usually appeared 80-120 ns after the x-ray peak. S. R. Mohonty et al. [9] developed a multiple Faraday cup assembly for measuring energy spectrum and flux of fast nitrogen ion beam emerging out of the pinched plasma column. The correlation of the ion beam flux with the filling gas pressure was estimated. Angular distribution of ion measurement showed that the highest ion beam flux is recorded at angle 5° with the axial direction while the lowest one is detected at 0° with the axial direction.

In this paper, the effect of gas pressure and charging voltage on the electron and ion beams emission characterizes and parameters is investigated and reported.

CONSTRUCTON OF PLASMA FOCUS EXPERIMENT AND DIAGNOSIS

A plasma focus PF device used in this work was designed and constructed with low electrical inductance in Plasma and Nuclear Fusion Dept., NRC, AEA .The plasma focus experiment under consideration is divided into two parts, the first part describes the coaxial electrodes assembly and the discharge chamber and the second part contains the energy storage system. The two dimensional view of the plasma focus PF device is shown in Fig.1 (a). The electrode system assembly shown in Fig.1 (b) consists of two electrodes which are made from stainless-steel material. The inner electrode has long of 13 cm and 4 cm in diameter surrounded by eight rods fixed symmetrically in a circle of 11 cm diameter around the inner electrode each of them has 0.8 cm in diameter and its length 13.6 cm as an outer electrode. A Teflon insulator ring is placed between the inner electrode and the outer electrode at the breech. The coaxial electrode system is enclosed in stainless-steel chamber of length and diameter 40 cm and 38 cm, respectively.

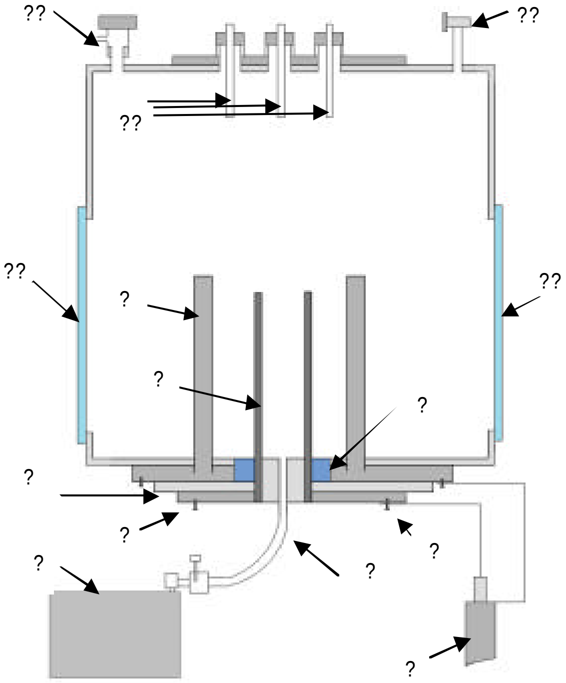


Fig.1 (a) Schematic diagram of the plasma focus device

?- ŽA?sAÐAdLG? ;?? ÐA dLG???? -Z?ddG? l?dG?? -Rotary pump.
?-Copper flange. ?-Connection poiYl???? -Teflon insulators.
?-K?lG? GLGÐl?ŽEG?? -Inner electrode. ??- Diagnostic tools.
??- ' A? sYLGl??-sAÐ??w OA?OG???- Glass slits.

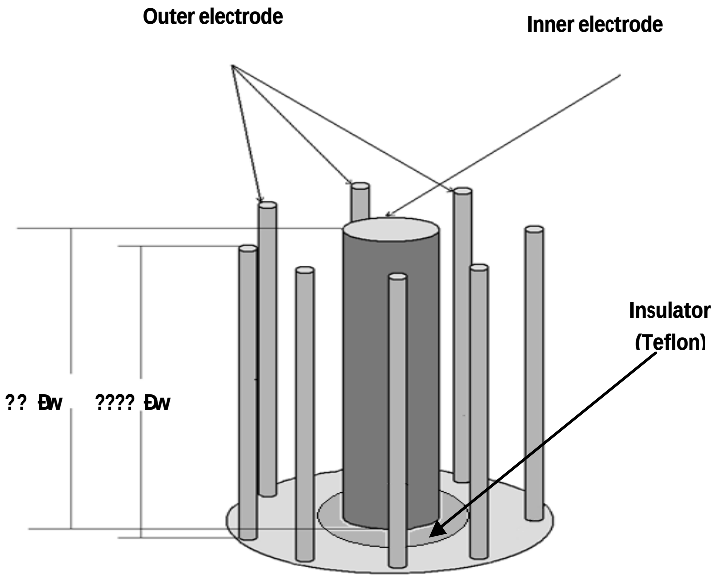


Fig.1 (b) schematic diagram of the coaxial electrodes system.

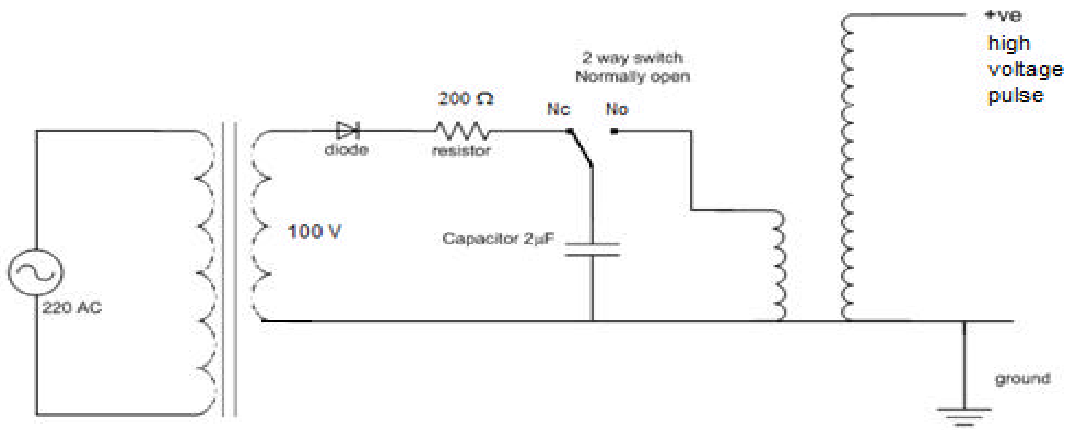


Fig.1 (c) The electric circuit of the triggering system

The energy storage system used in our experiment composes of 4 low-inductance capacitors which are connected in parallel,(C=4×7.71 µf),the maximum storage energy of the used capacitor bank is 2.2 kJ corresponding to a bank charging voltage of 12 kV . The capacitor bank is charged by a constant DC power supply through a limiting high resistance and it discharged through the coaxial electrodes assembly by a pressurized spark gap switch. A trigger system is designed to apply 30 kV to the trigger pole of a pressurized spark gap switch, Fig.1 (c) shows the electrical triggering circuit used for our experiment.

The diagnostic tools used in the experimental work include a Rogowsky coil to monitor the discharge current while a Faraday cup detector was used to reveal the time history of charged particle beams emission from a plasma focus. A velocity as well as intensity of the beam can be deduced from the time history of particle beams emission. Basically Faraday cup consists of metallic disk as the charge collector. The unbiased Faraday cup employed in this work and it fixed at 22 cm from the coaxial electrodes muzzle to detect the time resolved of ion beams and electron beams during the first and second half cycles of discharge respectively. Fig.2 shows the location of Faraday cup with respect to the charged particle beams.

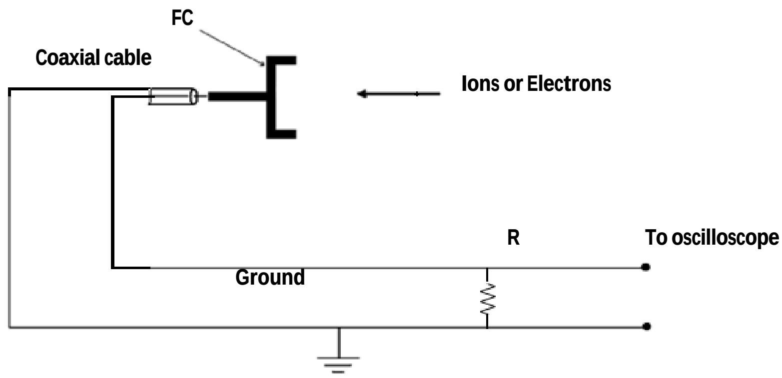


Fig.2 Schematic diagram of the used Faraday cup

EXPERIMENTAL RESULTS AND DISCUSSION

The discharge current in our experiment has an oscillating form, (a damping sinusoidal wave form), then the inner electrode of the coaxial electrodes system has a (+ve) and (-ve) polarity for the first and the second half cycle of discharge respectively. Then during the first half cycle, the FC detector measures the ion beams current while at the second half cycle, it measures the electron beams current. Measurements of variation of charged particle beams intensity with argon filling pressures in the range from 0.5 to 2 Torr, at various charging voltage from 8 to 12 kV and during the first and second half cycles of the discharge are shown in figures3 (a, b, c).

Figures 3 (a, b, c) show that the charged particle beams intensity tends to increase with increasing of most gas pressure values. Also, it is observed that the second half cycle has approximately the same behavior for all charging voltages under consideration.

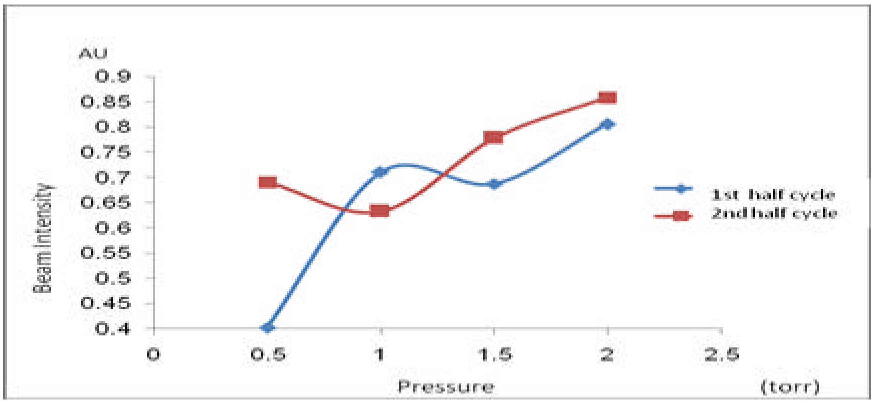


Fig.3 (a) variation of charged particle beams intensity with argon filling pressures at charging voltage 8 kV

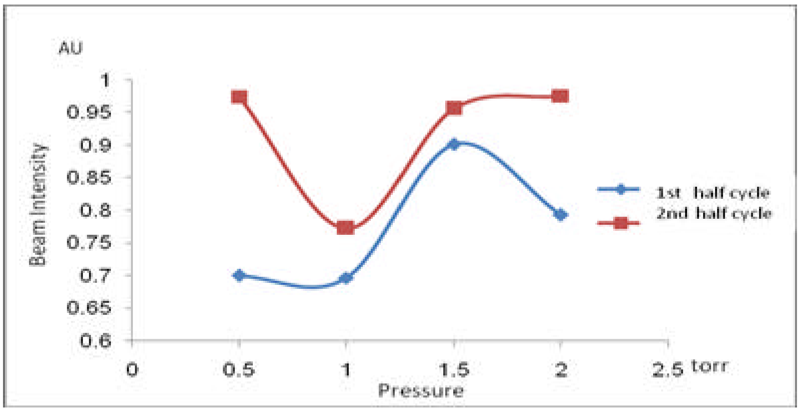


Fig.3 (b) variation of charged particle beams intensity with argon filling pressures at charging voltage 10kV

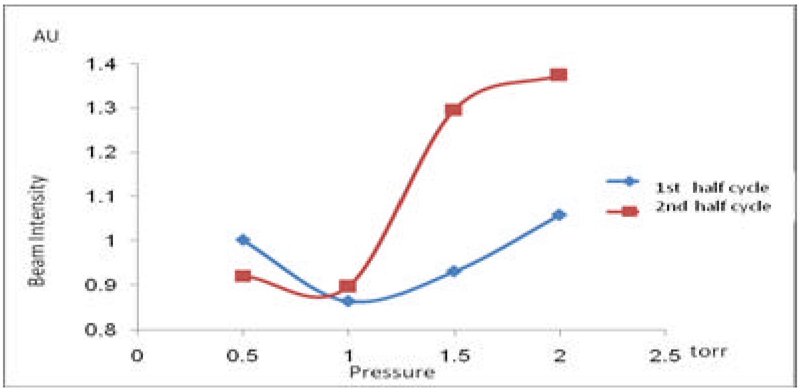
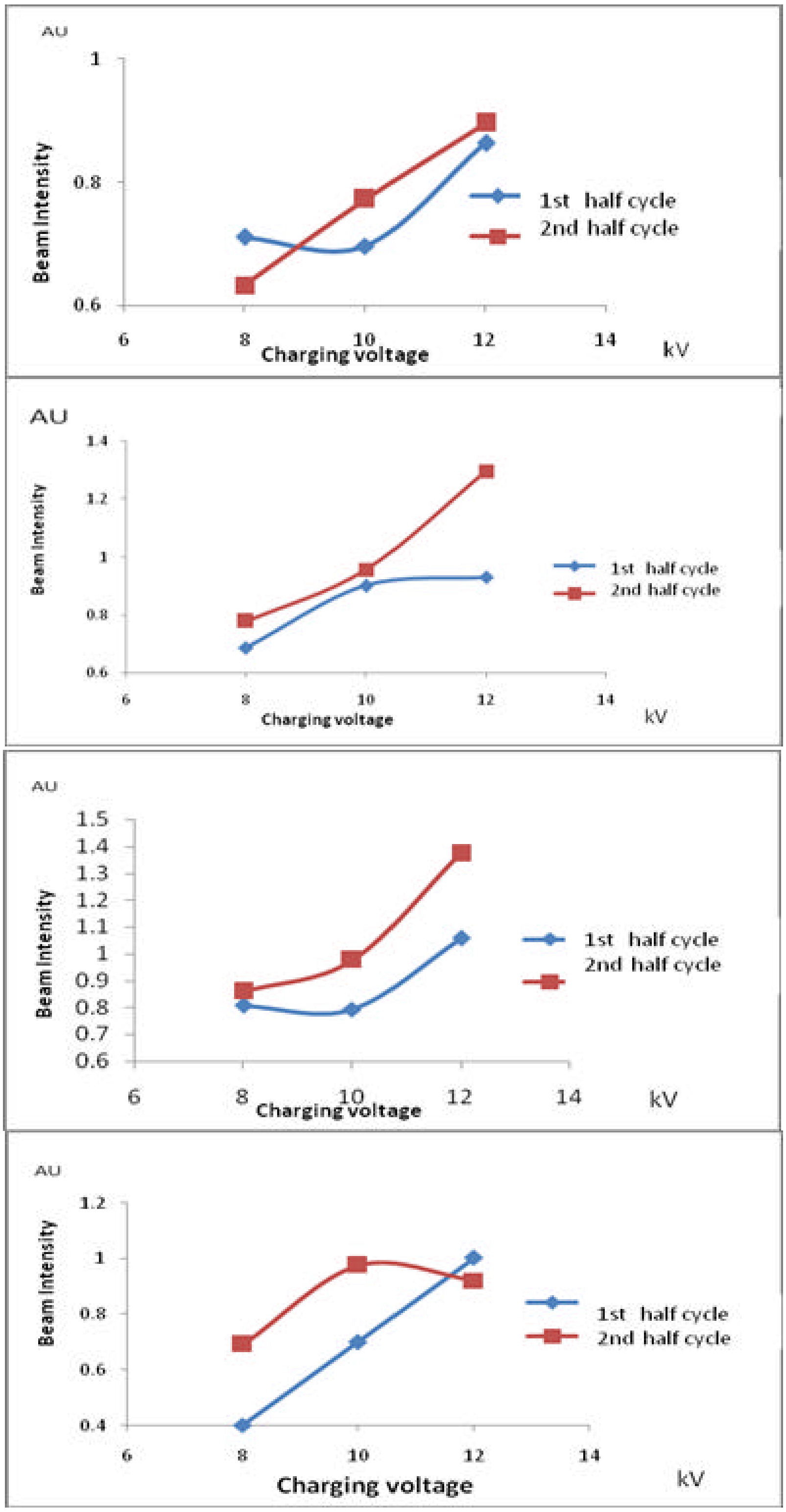


Fig.3 (c) variation of charged particle beams intensity with argon filling pressures at charging voltage 12 kV .

Variation of charged particle beams intensity with charging voltages and at different argon filling pressures 0.5, 1, 1.5, 2 Torr was measured during the first and second half cycles of discharge, as shown in figures 4 (a, b, c, d).



(a)

(b)

(c)

(d)

Fig.4 Variation of charged particle beams intensity with charging voltages at different argon filling pressures:

(a) 0.5 Torr **(b) 1 Torr**

(c) 1.5 Torr **(d) 2 Torr**

These four figures show clearly the increase of charged particle beams intensity with the increase of charging voltages for most values of charging voltages under consideration at 1st and 2nd half cycles of discharge and at different gas pressures. Also these figures show that the 2nd half cycle has approximately higher particle beams intensity than the 1st half cycle for all working parameters under consideration.

The variation of particle beams intensity with argon filling pressure for different charging voltages is shown in figures 5 (a, b) for the first half cycle and the second half cycle respectively. These figures illustrate that the charged particle beams intensity tends to increase approximately with increasing of gas pressure. Also, it has a maximum value at V_{ch} = 12 kV and P - 2 Torr for 1st and 2nd half cycles .

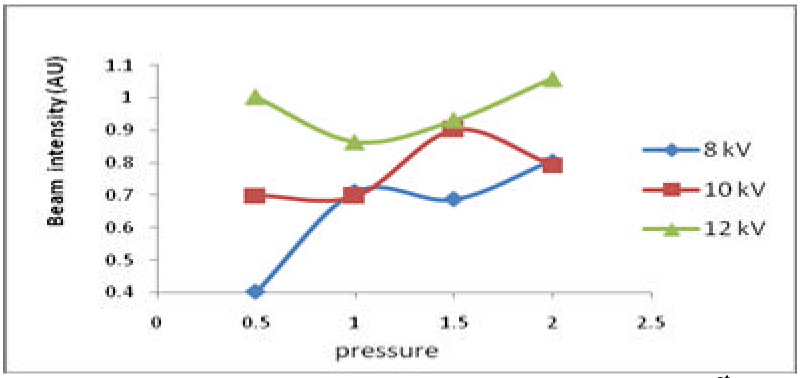


Fig.5 (a) Ion beams intensity vs. gas pressure at 8, 10, 12 kV (1st half cycle).

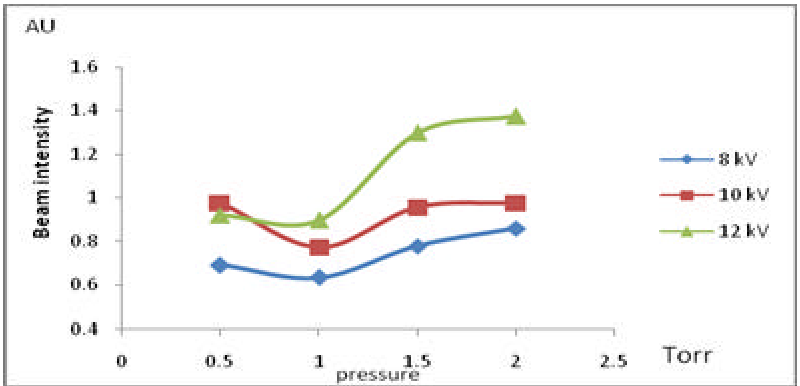


Fig.5 (b) Electron beams intensity vs. gas pressure at 8,10 ,12 kV (2nd half cycle).

Charged particle beams kinetic energy as a function of argon filling pressure for different charging voltages are shown in figures 6 (a, b) for the 1st and the 2nd half cycles respectively. It can be noticed from these figures that for the charging voltage of 12 kV , ion beams energy E_{ion} at the 1st half cycle increases gradually with the argon filling pressure and the maximum value of E_{ion} = 1.35 keV is detected at V_{ch} = 8 kV and p = 1 Torr. Also a maximum value of $E_{electron} \sim 2.56 *10^{-5}$ keV is obtained at V_{ch}=8 kV , and p=1.5 Torr. during the second half cycle and the energy of electron beams increases approximately gradually with gas pressures for V_{ch} = 12kV .

The density of ion beams and electron beams are estimated in arbitrary unit from the data of directed velocities and intensities of each beam during the first and the second half cycles of discharge process. Fig.7 (a, b) describes the relation between the density of ion beams, electron beams and the argon gas pressures for different charging voltages. These figures illustrate that at charging voltage = 8 kV and 10 kV , the variation of ion beams and electron beams density with gas pressure have approximately the same behavior for most values of charging voltage. The maximum value of ion beams and electron beams density is detected at charging voltage = 12 kV and gas pressure = 2 Torr and 1.5 Torr respectively.

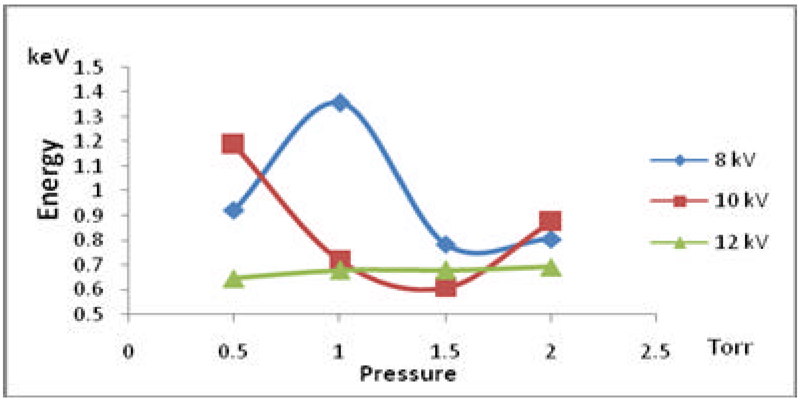


Fig..6 (a) Variation of ion beams kinetic energy vs. filling pressure at 8, 10, 12 kV (1st half cycle).

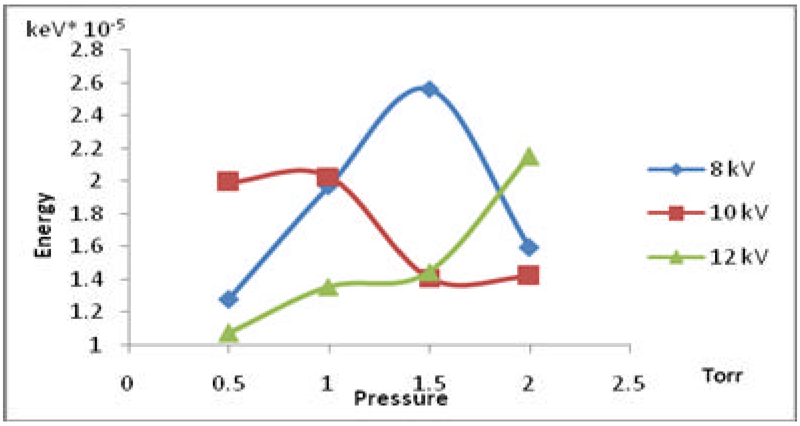


Fig.6 (b) Variation of electron beams kinetic energy vs. filling pressure at 8, 10, 12 kV (2nd half cycle).

CONCLUSION

The time resolved investigation of charged particle beams emission from our plasma focus device has been measured by using a Faraday cup assembly. The experimental results showed that the charged particle beams intensity, density and energy are strongly dependent on the operating discharge conditions under consideration. Analysis of experimental results illustrated that the charged particle beams intensity and density are increased with increasing of charging voltages for most values of filling gas pressures and the highest value of them is achieved at charging voltage=12 kV , gas pressure = 2 Torr for ion beams and 1.5 Torr for electron beams. To conclude we can say that our PF device is best optimized for charged particles emission with charging voltage =12 kV and gas pressure in the range from 1.5 to 2 Torr at this situation the PF column has a higher pinching and disruption due to a peak value of self magnetic force.

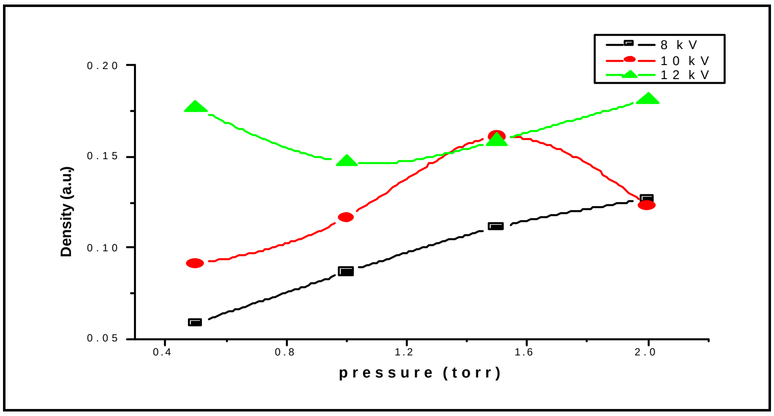


Fig .7 (a) Density of ion beams vs. filling gas pressure at 8, 10 and 12 kV (1st half cycle).

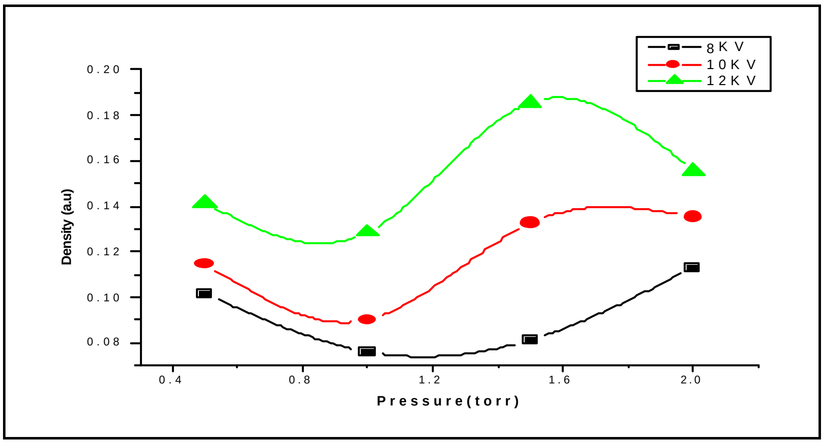


Fig.7 (b) Density of electron beams vs. filling gas pressure at 8, 10 and 12 kV (2nd half cycle).

The behavior of charged particle beams energy distribution with gas pressure and at different charging voltages has approximately a vise verse behavior of intensity and density of them, this situation may attributed to different collision processes. For such behavior, we may conclude that the production of a PF column can be utilized for a range of applications for ions or electron beams emission by the proper selection of operating conditions of filling gas pressure and charging voltage. However, this is not to be taken in a limiting sense.

In near future, the electron beams will be utilized for sterilization and lithography purposes. Also ion beams will be used for ion implantation, surface modification, thermal surface treatment and thin film deposition.

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