Analysis of the Ion Beams Generated in a Very Low-Energy Plasma Focus Device by a Linear Array of Faraday Cups

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Abstract. At present there is a growing interest in the development of very small PF devices operating under 1kJ for applications as radiation sources. However, more research is still required to achieve an efficient and reproducible miniature PF device to operate in repetitive mode, which would fit commercial purposes. An important difficulty in these devices is their low level of emission; therefore it is necessary to develop diagnostic and acquisition systems capable to measure these emission levels in single shot discharge. In this work, the charged particle emissions in hydrogen (H2) gas from a plasma focus device of 400 joules (PF-400J) are presented. In order to obtain an estimation of the ion energy spectrum and ionization degree, by using time of flight method, an array of Faraday cups operating in the bias ion collector mode was constructed and tested. The analysis of these measurements is made using a peak deconvolution routine applied to each ion probe signals. On the other hand, measurements of the flux and energy of the ions using CR39 SSNTD.

Introduction. It is an interesting phenomenon that high energy ions with energy of more than 1MeV are produced in plasma focus devices [1]. The energy is sometimes more than one hundred times as large as bank voltage. The mechanism of production of these ions has been investigated for several decades [2, 3]; however, the physical mechanism of production of these ions remains unclear. These energetic ions are considered to play an important role in the production of the intense neutron flux in the plasma focus device when using deuterium gas [4]. The determination of ion beam characteristics is very important not only in understanding the mechanism of production of high-energy ions or neutrons, but also for their applications.

In general, the studies of ion beams have been performed in plasma focus devices that operate with energies from 1kJ to 1MJ. In this work, results of some characteristics of emitted ions from a plasma focus device of 400 joules [5] are presented. In particular, the ion energy and ion current density was measured with two complementary methods like are a Faraday cup linear array and Solid State Nuclear Track Detector, CR39.

Experimental Setup and Diagnostics. The present experiment was conducted in a plasma focus device operating at an energy level of hundreds of joules (PF-400J, 880nF, 20-35kV, 176-539J, ~300ns time to peak current, dI/dt~4x1011 A/s). This device was designed and constructed at the Chilean Nuclear Energy Commission, CCHEN. The dimensions for copper anode and its alumina insulator, in PF-400J, were: anode radius r_a = 6mm; inner radius of the copper cathode r_c = 15.5mm; overall length of the anode z = 28mm; length of the alumina insulator l = 23mm. The discharge chamber was filled with hydrogen at a pressure of 10mbar, and deuterium at a pressure of 9mbar. A charging voltage of 27 kV was used.

Diagnostics include the usual voltage and current derivative probes, a Thomson spectrometer with SSNTD (CR39) as film [6], and a Faraday cup array used as an ion collector operating in the secondary electron emission mode, into the spectrometer (figure 1). The collectors are negatively biased to a dc -250V, because of the negative biasing the ion probes act as XRD. Also, the grid used to reduce SEE effects, it is connected to negative biasing of -100V [7]. Moreover, the x-ray and neutron emission was recorded by photomultipier-scintillator systems when deuterium gas was used.

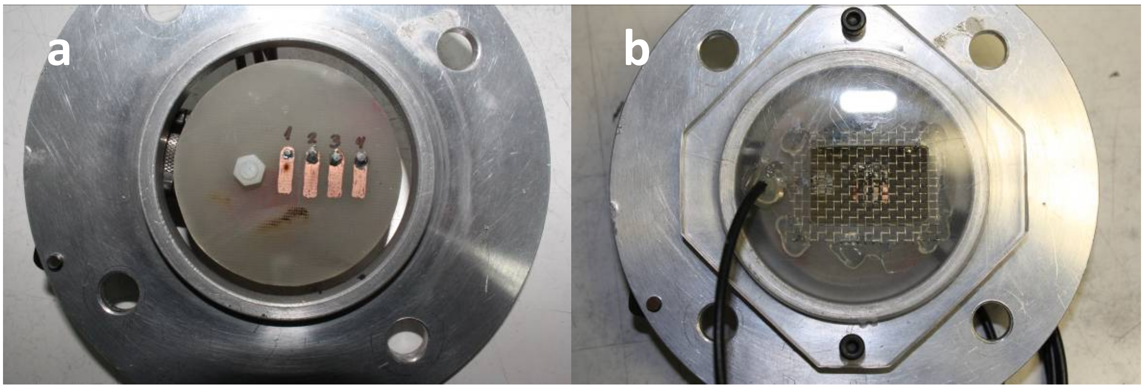

Figure 1. a) Faraday cup array. b) Grid to reduce effects of SEE.

The electromagnetic spectrometer arrangement consists of two rounds bar ceramic magnets (NdFeB) of 2.22 cm in diameter and 2.54 cm long are clamped by two disks, maintaining a certain pole gap as shown in figure. A radial distribution of magnetic field was found with an average value of 0.35T and a maximum, on the magnet axis, of 0.7T. The ion detector chamber (spectrometer), which acts as a drift tube, is separated from the Plasma Focus Device by a capillary tube of 0.8mm in diameter and 40mm in length. In order to minimize the ion beam attenuation in the background gas medium the ion detection chamber was kept at a lower pressure (~0.1mbar) than the main chamber, with the help of an additional pump. The CR39 film is localized 18cm on the top of the anode.

Results. Results obtained using SSNTD CR39, in hydrogen at 10 mbar, show that different distinct areas of the spectrum on the detector were identified. These areas can be defined as: Neutral band (1), Non-hydrogen charged particles (2) and Hydrogen spectrum (3), and the energy spectrum for this case is presented in the figure 2.

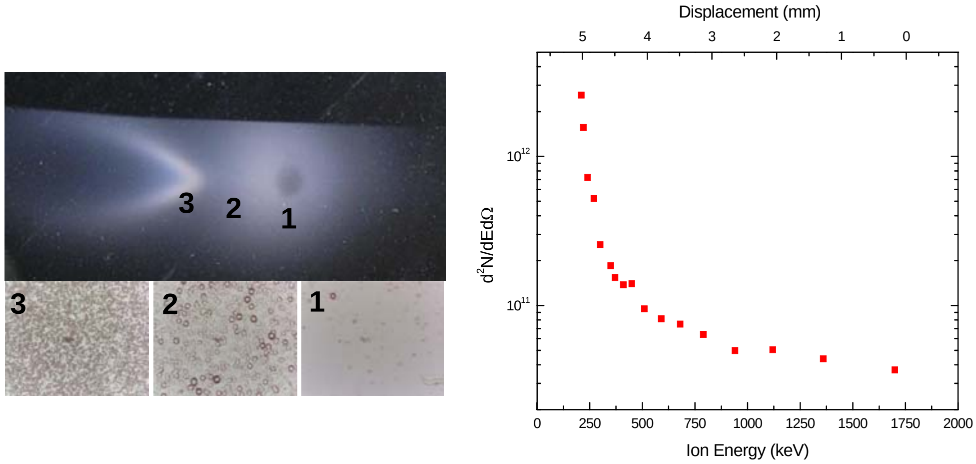

Figure 2. a) In the image, Measurements obtained with CR39 are shown. b) Plot shows an ion spectrum emitted from the PF-400J plasma focus device working in hydrogen at pressure of 10 mbar. The displacement is considered from zone 1 (0mm) to zone 3 (5mm) in (a).

The figure 3 show characteristic signals at 9mbar in hydrogen. From top to bottom: time derivative of the discharge current, faraday cups array signals FC1, FC2, FC3, and grid signal G1.

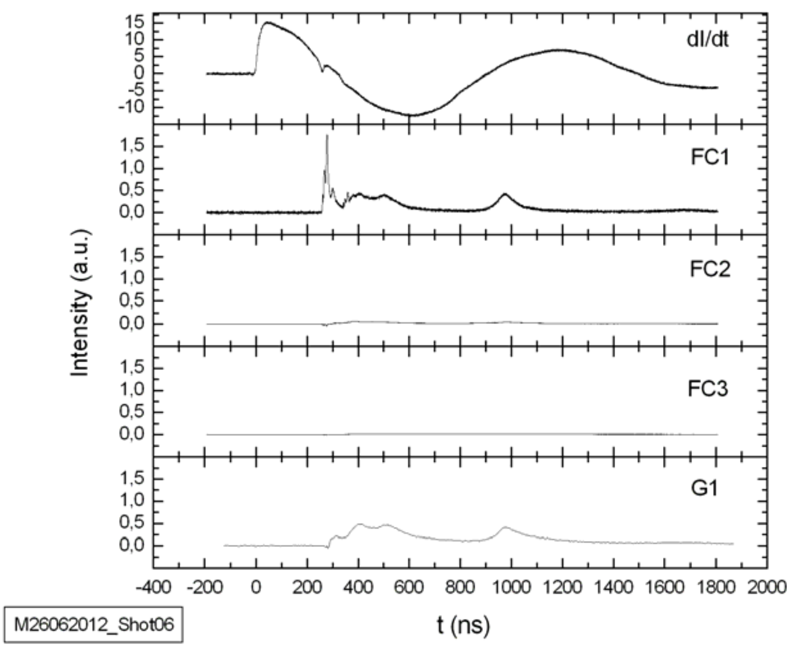

Figure 3. Faraday cup array signals and grid signal.

The velocity, energy and density of ions were estimated using the TOF technique. The ion velocity is estimated by taking the ratio of the distance to the flight time of ions from source to detector. The flight time of ions is deduced by correlating the FC signal with voltage or current derivative probe [8].

Table 1. Summary of measurements obtain using ToF and Ions Track Methods.

Device	Energy of Bank (J)	Gas	Pressure (mbar)	Ion Energy (KeV)	Technique
PF-400J	320	H2	9 to 12	200 to 1000	SSNTD
	320	H2	10	10 to 120	ToF
	320	D2	9	5 to 30	ToF

As summary of the results in this first stage, it is possible to mention that a Faraday cup array was implemented as a complementary diagnostic to the SSNTD method used in a Thomson spectrometer. The difference between the results obtained with both methods to energy range of the ions, in the H_2 case, could be explained from distinct response range of the SSNTD film and the electrical diagnostic. However, it is necessary to improve the data sampling and the method of analysis when the different techniques are used. The difficulties observed in this work will be identified and improved.

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