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NEUTRON MEASUREMENTS IN SAHAND PLASMA FOCUS

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Abstract. Experimental studies of neutron emission from a Filippov type plasma focus machine is reported here for different pressures and voltages in deuterium gas. The calibration method is discussed and time integrated and time resoled neutron signals and also the angular distribution anisotropy are studied in order to clarify the most probable mechanism for neutron production. The results showing the enhancement of neutron yield in the case of some krypton admixture is also presented.

1. INTRODUCTION

Plasma focus device is known as a powerful and excellent source of soft and hard x-rays,energetic ions and electrons as well as neutrons. Dense plasma focus(DPF) operation principles are given in different references (Filippov et al. 1962, Mather 1964, Siahpoush et al. 2005). Different stages are: the initial discharge state between the anode and ring-like insulator, the current sheet formation, ionization and capture of neutral gas (snow-plow model), accelerated motion of plasma current sheet (PCS), formation of non-cylindrical shock wave, development of instabilities, generation of x-rays and neutrons and finally the interaction of decayed plasma with electrodes surfaces. Using deuterium as the filling gas in the discharge chamber, fusion neutrons produced by D-D nuclear reaction are emitted from the device. The mechanism for neutron production in pinched plasmas is not exactly clear. There are two main mechanisms for neutron production in DPF devices. In one of these mechanisms, it is assumed that neutrons are generated in D-D reaction through collisions between deuterons. In the second likely mechanism, the accelerated deuterons colliding with thermal deuterons in the plasma bulk produce neutrons as the result of beam-target collision. The anisotropy shown in neutron and x-rays emission suggests that beam-target processes may be partly responsible for neutron generation. We give in this paper the variation of neutron yield as function of deuterium gas pressure. We also present some results from our neutron dosimetry monitoring around the machine.

2. EXPERIMENTAL SETUP

The experiments were carried out on the Filippov-Type dense plasma focus (DPF) facility called Sahand (Mohammadi et al. 2007). The two dimensional view of the DPF device is shown in Fig. 1. The cathode with a 75cm in diameter is made by stainless steel. The height of cathode is 26 cm. The copper anode made as a disc, 50 cm diameter, is fixed at the chamber centre with a cylindrical ceramic insulator, 48 cm in diameter, 11 cm high. The central part of the anode undergoes strong erosion because of high current concentration, ~ 1 MA, therefore it is made as an changeable insertion. The required energy for the production of discharge and focusing is provided by a capacitor bank of $288\mu F$ which consists of 24 capacitors. The maximum charging voltage is 25 kV and the maximum stored energy is 90 kJ which induces a discharge current of about ≈ 1.1 MA. For observing the neutron production the device is operated with Deuterium and Krypton as a working gas.

3. NEUTRON DETECTION AND DOSIMETRY

As it is mentioned in the introduction plasma focus is a source of neutrons with energies around E~2.45 MeV when one uses deuterium as the working gas. The integral neutron yield is measured with an activation detector consisting of a G-M counter surrounded by a silver foil of 0.1 mm thick and located inside a polyethylene moderator. Silver has a large activation cross section for thermal neutrons. The natural silver consists of two isotopes: Ag^{107} (51%) and Ag^{109} (49%). As the result of capturing a thermal neutron (E≤0.25 eV), two radioactive isotopes are produced: Ag^{108} with a half life of 145 s and Ag^{110} with a half-life time of 24.4 s. Induced radioactivity (mostly β particles) is measured immediately by a pulse counter device PS02-2eM. The detector is calibrated with Pu-Be neutron source having an activity of 7.22×10 neutrons/s. There is a linear correlation between the neutron yield and G-M count number. The neutron radiation in time can be registered with the detector based on a photo electron multiplier. It consist of PM-13

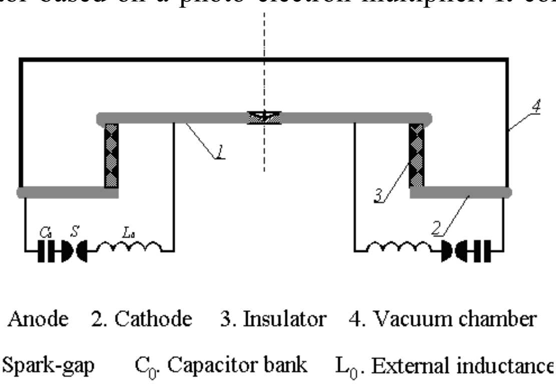

Figure 1: Schematic view of Sahand plasma focus.

type photomultiplier, fast plastic scintillator and voltage divider. The plastic scintillator serves to transform the radiation under study to the light emission. The given detector also resisters effectively the hard x-ray radiation. The separation of neutron signals from that of hard x-ray is possible because of different times of flight for hard x-ray and 2.45 MeV neutrons. For this purpose the detectors should be place at rather long distance from PF axis. A typical neutron signal is shown in Fig. 2.This signal is obtained with a gas pressure of 1 torr with a 3% krypton admixture at 16 kV. Here we used two photomultiplier tubes PM1and PM2. To prevent the transmission of x-rays PM1 is shielded in its front part by a 10mm Pb foil, while the other one can register both neutrons and x-ray. Maximum neutron yield of about 2.2×10^9 is obtained in the case of 18 kV and for pressures of 0.25 and 0.5 torr. According to this result, the time difference tends to a constant value in higher pressures. From radiation safety points specially when there is a relatively high flux (~10^{10}neutrons/s) of fast neutrons emitted from plasma focus. We made a general survey of radiation hazard using TLD (Thermo luminescent detector) in different positions and different distances from the PF axis. We used in our study ^{7}LiF crystal for HXR detection and two ^{6}LiF for neutrons and HXR. The crystals were placed inside a film badge including two cadmium filters. Comparing the measured values obtained from these two films, one can get the fast neutron dose.

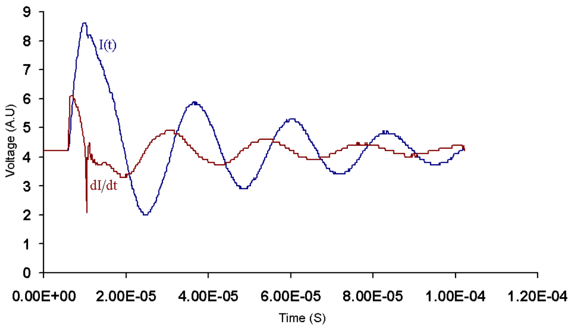

Figure 2:

4. CONCLUSION

Dosimetry measurements showed that the pinch does not occur in the centre and that neutron doses are at background level. Most neutrons are produced by beam target interaction compared with fusion neutrons with spherical symmetry. Some recommendations have been given for safety against x-rays.

References

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