*32nd EPS Conference on Plasma Phys. Tarragona, 27 June - 1 July 2005 ECA Vol.**29C**, P-1.128 (2005)*

Study of Gas Admixture Influences On The Pinch Dynamics In A 90 kJ Filippov Type Plasma Focus

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Abstract

In this paper we present an experimental work concerning the effect of gas admixture on the pinch dynamics in a Filippov type (25 kV, 288μF) plasma focus, DENA. Deuterium pressure of 0.3 – 1.5 torr and krypton admixture of 0.5% - 3% by volume, have been used as working gases. The main results have been obtained for the optimum pressure of deuterium and deuterium + krypton. A study of the time-resolved pulsed neutron signals by the time of flight technique made at angles of 0 and π/2 radians, show that the contribution of non-thermal neutron production in the quiet phase of deuterium discharges is not considerable; this is inconsistent for the Mather type plasma focuses.

Furthermore, the addition of krypton admixture to the deuterium working gas causes a sudden increase in the non thermal neutron production. A survey of the experimental results presents that the probabilities of multi-spike discharges are 75%and 20% with and without krypton admixture, respectively. The dip of negative spike in the current derivative signal for the case of krypton admixture is four times more than deuterium only gas discharges .The life time of the pinches, measured in terms of current derivative, were 60-180 ns with the gas admixture and 180 –200 ns without admixture discharges.

1. Introduction

In the plasma focus device a high-voltage discharge of a capacitor bank is produced in a coaxial electrode gun filled by a gas at a pressure of some mbars. A plasma sheath is generated on the insulator which separates both electrodes, and travels along the coaxial cavity .At the end of the gun, a radial implosion begins, moves towards the gun axis and forms a hot and dense plasma column, which is a few centimeters long and several mm in diameter .The focus has a duration of about 100-200 ns. The nature of the fusion reaction mechanisms in the plasma focus is still under debate. Generally two mechanisms are presented for neutron emission from the focused plasma [1,2], the first is thermonuclear mechanism in which, neutrons are produced from deuterium Maxwellian distributed plasma and second one beam target mechanism in which, the fusion reactions occur when a group of high energy deuterium ions interact with the cold plasma as a target. In the Poseidon [3] device, for example the fusion yield is up to a factor of 100 times higher than expected from purely thermonuclear reactions in the quiet phase as well as in the unstable phase.

In the most of plasma focus devices a double pulse structure of neutron emission is observed, clearly coincident with the quiet and unstable phases.

In the small and medium size of the plasma focus devices, first pulse is bigger than second pulse. In contrary, the second pulse in large PFD is bigger than the first one [4]. Two different sources of x-ray emission are present during focus evolution [5].

The main aim of this work was to investigate the effect of krypton admixture on the neutron production mechanisms in different phases of the pinch, through detection of neutrons and hard x-rays with a scintillator-photomultiplier system. This paper also presents a comparison of the experimental results concerning the current derivative signal characteristics in deuterium and deuterium+krypton discharges.

2. Experimental setup

The experiments have been performed in the Filippov type "DENA" plasma focus device [6]. The time resolved hard x-ray and neutron emission was measured by a photomultiplier (PM_53 type) coupled with a NE-102 plastic scintillator with a 5 ns resolution. We used a proper shield, made of lead and copper layers, for hard x-ray elimination from PMT signals. A G–M counter covered by an In foil with 0.23mm thickness placed within a polyethylene moderator records the total neutron numbers.

3. Results and discussion

In this work we have accurately determined time characteristics of the neutron and hard x-ray signals by comparing the PMT signals with and without hard x-ray filter (pb-cu filter), which completely stops the emitted hard x-rays.

Fig.1 and Fig.3 present the neutron and hard x-ray emission recorded by PMT+scintillator detector system with current derivative signal for the discharges of deuterium and deuterium+krypton working gases, respectively. The figures have obtained in the pressure of about 1 torr and krypton admixture 2% by volume (in the case of fig.3) at 16 kV discharge voltages. The time delay between hard x-ray and neutron productions in the device and their appearance on the oscilloscope due to long interface cable is about 130ns. This delay for the current derivative signal is about 40ns. The times corresponding to the time-of-flights of hard x-rays and 2.45Mev neutrons from the focus to the scintillator are 10ns and 140ns due to 3m distance of the detector to the pinch. So, considering the delays due to interface cables and time of flights; we observe the signal of hard x-ray and 2.45Mev neutron emission on the oscilloscope 140ns and 270ns after their productions in the device.

Fig.1 shows that hard x-ray signal, which is emitted by the non-thermal mechanisms in the pinch phenomenon, is coincide of the beginning of the pinch instability phase, and hence the contribution of the non-thermal neutron production in the quiet phase is not considerable; This is inconsistent for the Mather type plasma focus [3]. It should be noted that the neutron pulse in the PMT signal starts after the hard x-ray signal (it is evident from the fig.2). Fig.2 shows the PMT signal with the hard x-ray filter on PMT+scintillator tube. Some clear conclusion can be extracted from the results presented in fig.2. Neutron production, which is occurred in two separated pulses, is started at about of the maximum pinch compression (time difference between beginning of the neutron pulse and maximum compression is about 230ns). We have observed that about 70% of discharges show two neutron pulse modes.

It is evident from fig.2 that the second neutron pulse that is bigger than the first one starts from the end of the quiet phase and it is coincide with the hard x-ray pulse in fig.1.

With the addition of krypton into the major working gas, the beginning of hard x-ray signal is shifted to the early of quiet phase, which is evident from fig.3. It also is found that the non-thermal neutron production is started from the beginning of the quiet phase and ended to the plasma column disruption. This behavior is commonly observed in the axial and radial direction on plasma focus. It is concluded that using of krypton admixture increases the contribution of non-thermal mechanisms in neutron production.

A statistical study shows that 75% and 20% of shots appear as multi-spike pinches with and without krypton admixture, respectively. We have observed that about 70% of discharges show two neutron pulse modes in both working gases.

The above results could be explained on the basis of actual Z of the gas admixture. The presence of krypton admixture (high Z component) would lead to a higher ionization and radiation loss both at during the radial compression and pinch phases.

The increase in losses would effectively reduce the shock to piston separation during the

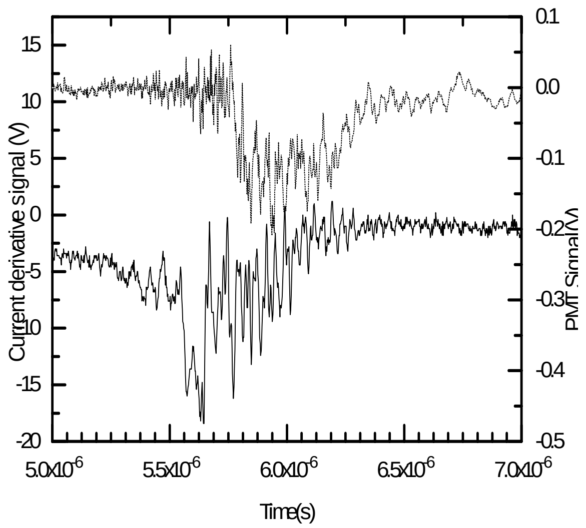

Figure 1. Oscillograms of: PMT signal (upper trace) and current derivative signal (lower trace) for deuterium discharge.

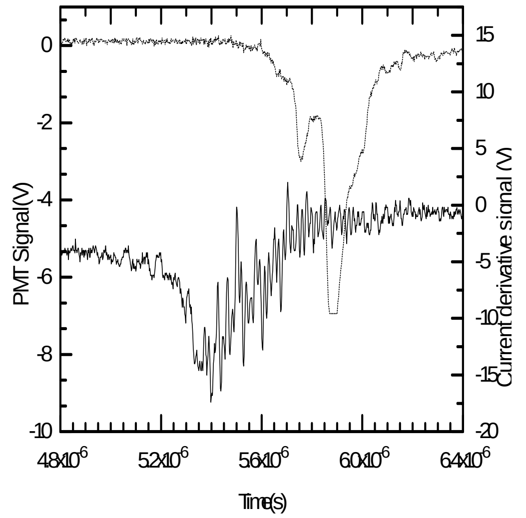

Figure 2. Oscillograms of: PMT signal with hard x-ray filter (upper trace) and current derivative signal (lower trace) for deuterium discharge.

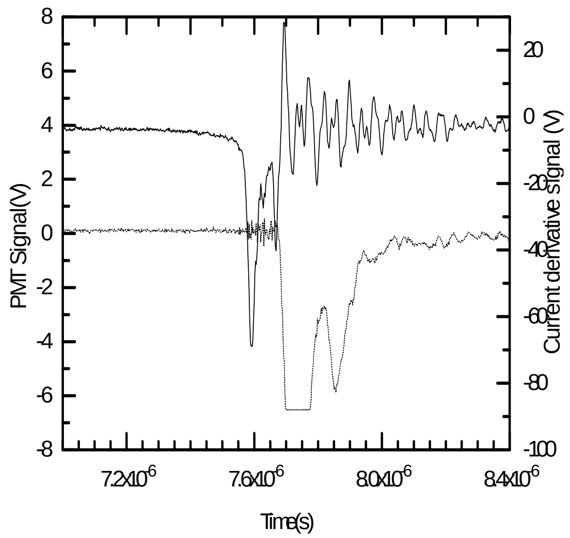

Figure 3. Oscillograms of: Current derivative signal (upper trace) and PMT signal (lower trace) for deuterium+2% krypton discharge.

compression and thus leading to a thinner plasma sheath; followed to the formation of the dense pinch, the much higher level of radiation losses would then cool the pinch column quickly tends to a lower radius of plasma column and deeper negative spike on the current derivative signal. It seems that the beam target mechanisms can be amplified in proportional to the decrease in pinch radius independent of gas type.

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