*31st EPS Conference on Plasma Phys. London, 28 June - 2 July 2004 ECA Vol.**28G**, P-2.016 (2004)*

Effect Of Sparkgap Breakdown And Current Buildup Speed On Filippov-Type Plasma Focus Experiments

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Abstract

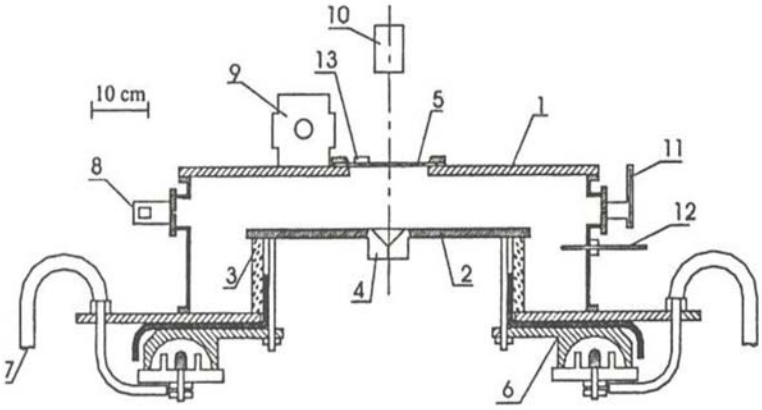
We have studied the relation between the sparkgap operation parameters and the plasma pinch and Neutron yield in our Filippov-type plasma focus, Dena, with 90kJ energy storage bank (25kV, 0.288mF). It has been found that better pinches (at the same conditions) with regard to their Neutron yield, generally are associated with a faster breakdown in the triggerable sparkgap as well as higher current buildup rate. We have measured the current buildup speed at various operating conditions and derived the experimental primary ionization parameter and drift velocity of electrons, at extremely high field to pressure ratios. Also, an elaborate axisymmetric variational time-domain finite element simulation code has been developed, in support of the experimental measurements. The code takes the effect of primary, secondary, and photo ionization mechanisms in discharge evolution of the sparkgap.

Introduction

One of the most efficient small fusion devices is the plasma focus. It has proved a useful source for a variety of phenomena like pinch formation, neutron, X-ray generation and ion beam generation in hot plasmas. A lot of experimental and theoretical works for the optimization of plasma focus devices have been performed [1-5]. The effects of geometrical and operational device parameters on the plasma dynamics and pinch productions are well known. In this paper we have experimentally studied the effect of sparkgap operation parameters and its current breakdown on neutron yield.

Results and discussion

We have studied the relation between the sparkgap operation parameters and the plasma pinch and Neutron yield in our Filippov-type plasma focus, Dena, with 90kJ energy storage bank (25kV, 0.288mF) [6]. Schematic cross section of this installation is shown in Fig. 1.



1. Cathode 2. Anode 3. Insulator 4. Insert anode 5. Upper flange 6. Sparkgap 7. Cable 8. PIN diode 9. Geiger-Muller Counter 10. PMT 11. Pinhole camera 12. Magnetic Probe 13. TLD

Fig. 1. Schematic of the Filippov-type Dena plasma focus.

It has been found that better pinches with regard to their Neutron yield, generally are associated with a faster breakdown in the triggerable sparkgap as well as higher current buildup rate. We have measured the current buildup speed at various operating conditions and derived the experimental primary ionization parameter and drift velocity of electrons, at extremely high field to pressure ratios.

In Fig. 2 the current derivative signal from the magnetic probe recorded by a 5GS/sec digital storage oscilloscope is shown.

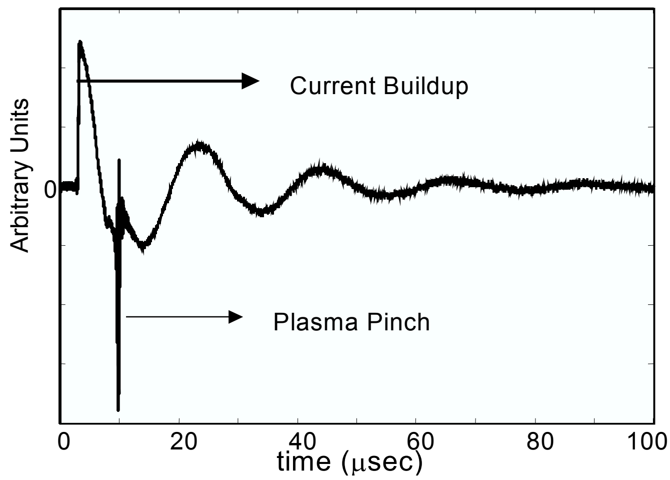


Fig. 2. Current derivative signal from the magnetic probe.

Enlarging a short period of the current derivate curve over the initial current buildup, as illustrated in Fig. 3, reveals a series of rapid oscillations in the current. Simulations show that these oscillations are connected to the drift of electron wavefronts, or the so-called streamers, across the gap. Each electron streamer along its way to the anode electrode breaks the gas molecules into electron-ion pairs, resembling the avalanche mechanism in solid-state p-n junctions. Meanwhile, the photons emitted by excited molecules propagate to the cathode surface, releasing extra free electrons into the breakdown channel, and a new streamer begins to develop. After some time, the first electron streamer reaches its end of path to the anode electrode and the moving electrons would be absorbed there. This produces a series of falls in the current derivate as shown in Fig. 3, enabling one to measure the electron drift velocity.

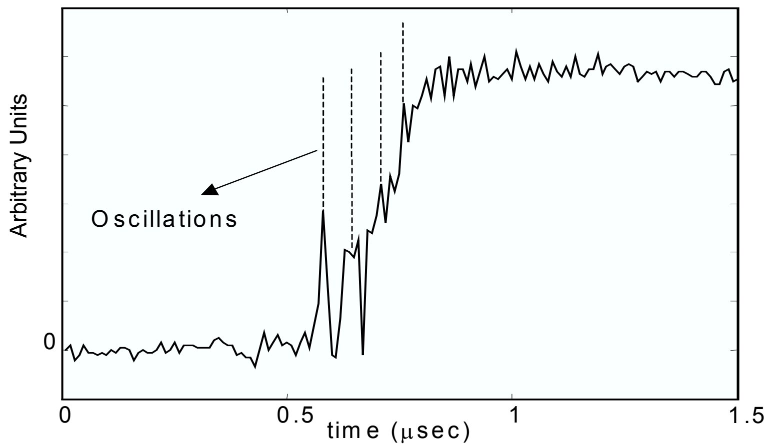
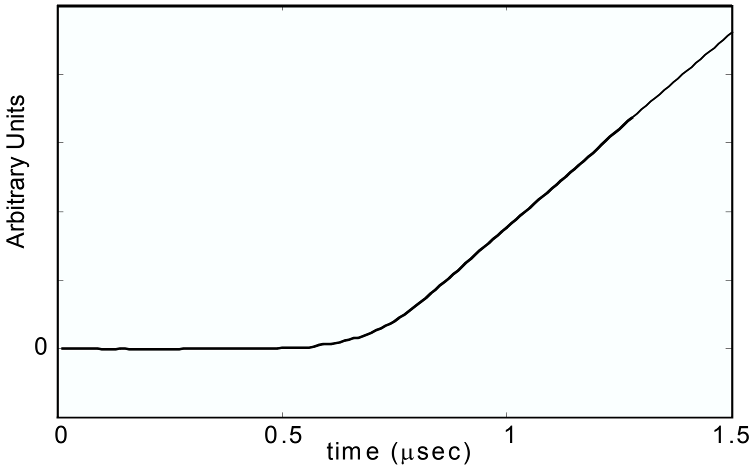


Fig. 3. Current derivate in the buildup stage.

Once we have measured the current derivative, the total current flowing into the sparkgap can be obtained by numerical integration. It can be seen that for the given shot, the current rise is almost linear, which is the characteristic of a weak breakdown as shown in Fig. 4a. In contrast, strong breakdowns have exponential current rises, as shown for another shot in Fig. 4b. We have noticed that faster breakdowns usually would lead to higher neutron yield in the forthcoming plasma pinch.

Also, an elaborate axisymmetric variational time-domain finite element simulation code has been developed, in support of the experimental measurements. The code takes the effect of primary, secondary, and photo ionization mechanisms in discharge evolution of the sparkgap.



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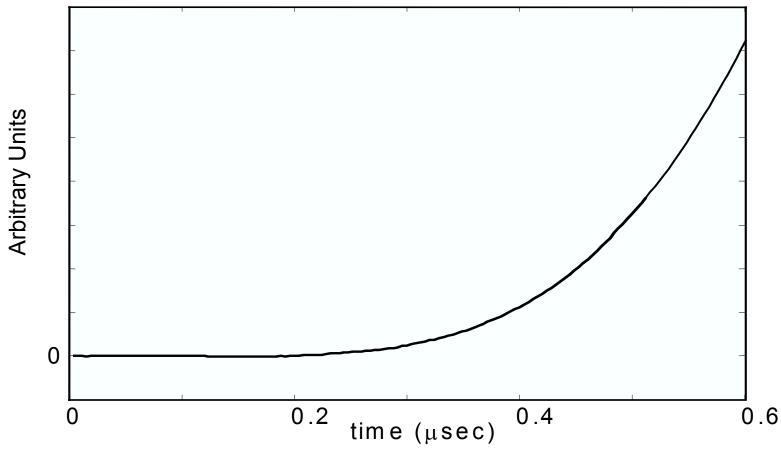

b

Fig. 4. Current buildup during the initial breakdown:

a. weak breakdown with linear rise; b. strong breakdown with exponential rise.

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