Multiple pinching in the miniature plasma focus nanoPLADEMA

M Barbaglia\textsuperscript{1}, L Soto\textsuperscript{2} and A Clausse\textsuperscript{1}

\textsuperscript{1}CNEA-CONICET and Universidad Nacional del Centro, 7000 Tandil, Argentina
\textsuperscript{2}Comisión Chilena de Energía Nuclear, Santiago, Chile

E-mail: barbagli@exa.unicen.edu.ar

Abstract. This work presents evidence of multiple pinching deduced from electrical diagnoses taken during discharges on the Plasma-Focus nanoPLADEMA, of extremely low energy. The dimensions of the anode are 2mm OD and 0.5mm length, the insulator is an alumina tube 4 mm OD and 2.3 mm length. The cathode is open, so the current sheet expands radially free.

1. Introduction
Low energy Plasma Foci (PF) are attracting increasing interest for their potential applications and portability as neutron and x-ray sources. Comparing with isotopic neutron sources, PF have unique qualities as a source of x-ray/neutron pulses, emitting only on operator demand, with low risk of radiation contamination and low cost of operation and maintenance. PF devices not only are interesting for basic plasma research but also for industrial applications [1] ranging from tailored soft x-ray sources [2,3] and soft x-ray microlithography [4] to hard x-ray introspective imaging of metallic pieces [4-9], neutron production and applications [9,10] and plasma thrusters [11] among others.

The exploration of the lowest energy possible in the plasma focus devices was, among others, a main goal to achieve in a cooperation research project between the National Atomic Energy Commissions from Argentina and Chile. Two similar devices were designed and built in each of these countries [12]. The Chilean device was named “Nanofocus” (not to be confused with the 100J PF reported by Milanese et al. [13]), and the Argentine device was called “NanoPLADEMA”. The present work was conducted in the latter.

2. Experimental arrangement
The schematic of the apparatus is shown in figure 1. A pair of 200 mm diameter brass electrodes acts as a final capacitor to drive the discharge. A 1.6 mm Cooper tube covered with alumina is attached to the center of the anode plate and passes through a small hole in the cathode center. Four dielectric PVDF films, 80 \(\mu\text{m}\) thick, were placed between both plates. The measured capacity is 4.9 nF. The total dimensions of the discharge chamber are 20cm\(\times\)20cm\(\times\)5cm. A transmission line attached to a spark-gap connects the discharge camera with the primary energy source that is accumulated in the capacitor 3 in figure 1. Figure 2 shows a photograph of the complete system. The high voltage current source to energize capacitor 3 (figure 1) and the vacuum system are not displayed in the picture.
3. Results
The device was operated in 5 mbar of Hydrogen, charging at 5kV. The current derivative passing through the anode, $\frac{dI_a}{dt}$, was measured with an independent Rogowski coil placed inside the anode plate. Meanwhile, the current derivative history that flows to and from the camera, was measured with another Rogowski coil, $\frac{dI_e}{dt}$. It should be noted that the current inside the chamber and the current in the external circuit are not equal during transients due to charge accumulation in the plate capacitor. Both Rogowski coils have similar temporal response.

![Figure 1](image_url)

**Figure 1:** Schematic diagram of the Plasma Focus nano-Pladema. 1: power supply, 2: charging resistance, 3: capacitor 4.9 nF, 4: spark-gap, 5: anode, 8 cathode, 5 and 8: pair of 200 mm diameter brass electrodes forming the capacitor to drive the discharge (5 nF), 6: anode, 7: dielectric, four PVDF films of 80 μm thickness, 9: cathode, 10: optical windows, 11: discharge chamber, 12: alumina tube, 13: anode, 14: plasma sheath between anode and cathode.

Figure 3 shows the signals of the anode voltage and current derivative in the anode and the external circuit, recorded during a discharge at 5 mbar of hydrogen. Three spikes of the anode current derivative can be identified at 0.6 μs, 0.85 μs and 1.45 μs. These events correlate with smaller spikes of the anode voltage. The absence of spikes in the external current derivative precludes the interpretation of the spikes as line reflections. The usual interpretation of these correlated spikes in PF devices is the occurrence of sudden inductance changes. Since by construction the device cannot produce changes in the inductances, it is reasonable to conclude that the spikes displayed in figure 3 are brought about by plasma inductance changes inside the discharge chamber, probably associated with pinching phenomena.

4. Conclusions
The spikes observed in the anode Rogowski signal indicate the occurrence of multiple pinching in different periods of the discharge oscillation. The absence of spikes in the external current derivative precludes the interpretation of the spikes as line reflections, thus supporting the present claim. Similar multi-pinching phenomena were already reported in previous experiments in small Plasma-Focus devices [14] also in the same work, it was reported the hard x-ray production in multi-pinch phenomena. To the present, the physical explanation of this sort of phenomena in small PF devices is a pending task.

Currently the neutron and x-ray emissions are being studied in discharges in deuterium. However, the expected yield is under the detection threshold of typical detectors used in ordinary plasma focus research. New techniques are under study to guarantee the accuracy of the measurement.
Discharge chamber
Charging resistance
Energy source capacitor
Spark gap
Transmission line

**Figure 2:** Photography of the plasma focus device *nanoPLADEMA*.

![Graph](image)

**Figure 3:** Signals of a discharge from *nanoPLADEMA* at 5 mbar of hydrogen, 5kV, showing the current derivative through the anode \((dI_a/dt)\), the anode voltage \((V_a)\) and the current derivative through the external circuit \((dI_e/dt)\).
References

[1] Moreno C, Venere M, Barbuzza R, Del Fresno G, Ramos C, Bruzzone H, Florido P, González J and Clausse A 2002 Braz. J. Phys. 32 20–5
[2] Zakaullah M, Alamgir K, Shafiq M, Sharif M, Waheed A and Murtaza G 2000 J. Fusion Energy 19 143–57
[3] Hussain S, Ahmad S, Khan M Z, Zakaullah M, and Waheed A 2004 J. Fusion Energy 22 195–200
[4] Lee S, Lee P, Zhang G, Feng X, Gribkov V, Liu M, Serban A and Wong T K S 1998 IEEE Trans. Plasma Sci. 26 1119–26
[5] Moreno C, Clausse A, Martinez J F, Llovera R and Tartaglione A 2001 Nukleonika 46 S33–4
[6] Venere M, Moreno C, Clausse A, Barbuzza R and Del Fresno G 2001 Nukleonica 46 (Supplement 1) S93
[7] Raspa V, Sigaut L, Lloera R, Cobelli P, Knoblauch P, Viytes R, Clausse A and Moreno C 2001 Braz. J. Phys. 34 696–9
[8] Silva P, Moreno J, Soto L, Birstein L, Mayer R and Kies W 2003 Appl. Phys. Lett. 83 3269
[9] Raspa V, Moreno C, Sigaut L and Clausse A 2007 J. Appl. Phys. 102 123303
[10] Tartaglione C, Ramos C, Clausse A and Moreno C 2004 Braz. J. Phys. 34 1756–8
[11] Scheuer J T, Schoenberg K F, Gerwin R A, Hoyt R P, Henins I, Moses R W Jr, Black D C and Mayo R M 2001 IEEE Trans. Plasma Sci. 22 1015–33
[12] Soto L, Pavez C, Moreno J, Barbaglia M O and Clausse A 2009 Plasma Sources Sci. Technol. 18 015007
[13] Milanese M, Moroso R and Pouzo J 2003 European Physical Journal D 27 77-81
[14] Barbaglia M, Bruzzone H, Ríos I, Acuña H, González J and Clausse A 2010 Plasma Phys. & Control. Fusion 52 032001