# Preliminary Results of a 10 kJ Z-Pinch

O. D. Cortázar[a], A. R. Piriz[a], G. Rodríguez Prieto[a], D. H. H. Hoffmann[b] and N. A. Tahir[b]

[a] *Universidad de Castilla-La Mancha. E.T.S.I.I.*
*Laboratorio de Plasmas y Descargas Eléctricas*
*Campus de Ciudad Real – 13071 Ciudad Real – Spain*
*daniel.cortazar@uclm.es*

[b] *G.S.I Darmstadt – Plasma Physics Division*
*Planckstr. 1 - 64291 Darmstadt – Germany*

**Abstract.** Preliminary results obtained on 10 kJ Z-pinch device developed at the Plasma and Electrical Discharge Laboratory in the University of Castilla-La Mancha are presented. The device called ENERGU-1 is composed by 8 capacitors (0.5 μF, 75 kV, 20 nH) connected in parallel to a discharge chamber by means of one high power plane transmission line by mean of 8 spark-gaps switches triggered by a 100 kV, 13 ns trigger pulse. The discharge chamber is a cylindrical Pyrex glass tube externally surrounded by a $SF_6$ isolation atmosphere with the electrodes at the ends. Two different chambers have been studied by discharging the capacitor bank energy in deuterium for optimizing the D-D nuclear fusion reactions: one of 100 mm long by 100 mm inner diameter and the other of the same length and 70 mm inner diameter. Several sequences of ultrahigh speed converter camera photography (5 ns) are presented showing the implosion of plasma columns for different deuterium pressure and currents. Preliminary measurements of integrated 2.45 MeV neutron emissions by a silver activated neutron counter are analyzed as a function of electrical and constructive parameters. A yield of $10^7 – 10^8$ D-D fusion reactions by shot is reported when the optimum conditions are reached conducting currents of 400-600 kA with a plasma column lifetime above 100 ns.

**Keywords:** Dense Magnetized Plasmas, Z-pinch, Nuclear Fusion
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## INTRODUCTION

A deep and extended revival of the Z-pinch experiments in the plasma and fusion community have been developed driven by the spectacular advance made during the last decade reaching high energy density by means of the implosion of annular current sheaths[1]. The Dense Z-pinch offers an efficient means of coupling magnetic energy into plasma to produce hot and dense matter, which is relevant for nuclear fusion. On the other way, the physics involved around the formation and implosion processes of a cylindrical plasma sheet is especially interesting from the point of view of plasma instabilities where the Z pinch is a textbook example. Besides powerful x-ray sources, there have been developed in x-ray lasers using a capillary discharge Z-pinch[2], and studies of direct magnetic fusion and radiative collapse[3]. Considering the reachable technology associated to small scale Z-pinch experiments, university laboratories are producing interesting results by researching the broad spectrum from x-ray generation to controlled thermonuclear fusion in small self developed devices. On such way we are focusing our efforts starting an experimental research program in plasma physics and nuclear fusion at the University of Castilla-La Mancha in Ciudad Real, Spain were the ENERGU-1 is our first device recently started. We present herein the preliminary results describing the discharge system and performance by means of ultra high speed photography and some measurements of neutron pulses detected by a silver activated neutron detection system.

## DEVICE DESCRIPTION

The ENERGU-1 is a 10 kJ, 700 kA Z pinch completely designed and constructed at the Laboratorio de Plasmas y Descargas Eléctricas in the Universidad de Castilla-La Mancha. The device produces a collapsing plasma current sheath by discharging a bank of eight 0.5 μF, 75 kV, 20 nH capacitors on a cylindrical glass vessel with a pair of brass hole electrodes inside separated 100 mm. Each capacitor is driven by one spark-gap pressurised with synthetic air and triggered by a pulse of 100 kV, 13 ns risetime. In order to keep the isolation, each spark-gap is mounted inside of a cylindrical aluminium piece. Such housing pieces have the double function of connecting the capacitor's ground to the transmission line plate keeping the spark-gap switches under an atmosphere of $SF_6$ for avoiding the external flash-over discharge. Figure 1(a) shows a partial view of five capacitors during different stages of pulse power system mounting where it can be seen how the spark-gap housings are fixed to the capacitor's carcase containing the switches. Rowgosky coils are inside of each housing piece for measuring the current discharge of each capacitor independently. Theses eight current measuring signals allow to measure the current discharge and to check the timing between individual capacitors currents verifying if the system is firing correctly.

Figure 1(b) shows the entire power switching system before mounting the transmission line and Figure 1(c) shows the full system mounted ready for firing. The power transmission line is composed by two parallel plate isolated by a 500 micron Mylar sheath. Such line connects the capacitor bank to the discharge chamber which is a coaxial set up that use an external set of brass for connecting the positive electrode. These arrange permits to observe the plasma sheath from the lateral side ($\theta$ direction). Figure 1(d) shows a close-up of the discharge chamber where it can be seen the brass rods surrounding the vessel. An external envelope made of a transparent acrylic tube that keeps an external atmosphere of $SF_6$ around the vessel in order to avoid undesired flashover discharges.

The trigger power supply of 100 kV – 13 ns, is connected to the spark-gaps by means of $SF_6$ isolated distribution system including a capacitive filter in order to disengage the HV DC component on the spark-gaps trigger electrodes. The gas pressure gauge is a capacitive absolute measuring system connected to the discharge chamber in order to measure the $D_2$ pressure on the range of 0.1 – 10 torr.

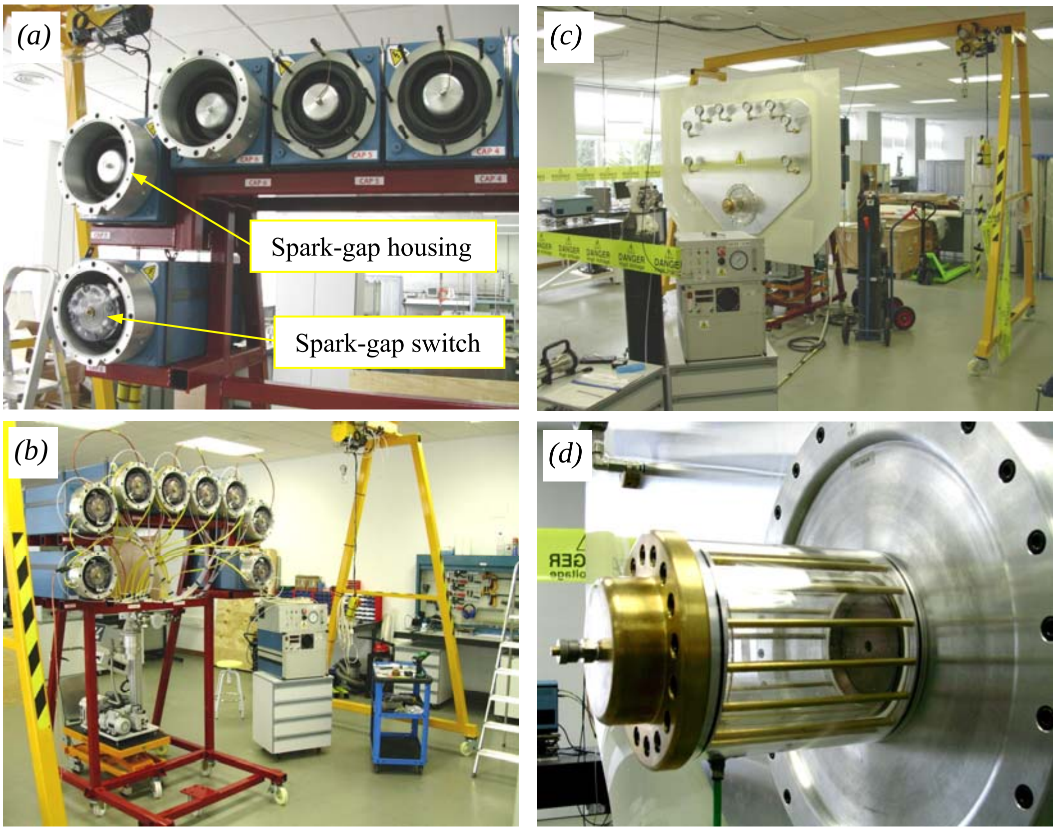


**FIGURE 1,** Different stages of the z-pinch machine development. (a) View of the spark- gap housing and switches mounting. (b) All Switching system ready for mounting the transmission line. (c): The machine full mounted and ready for firing. (d) A discharge chamber close-up.

## DYNAMIC STUDY BY HIGH SPEED PHOTOGRAPHY

A Cordin 222-16 ultrahigh speed image converter frame camera (ICC) was used for obtaining sets of 8 pictures of 5 ns exposure time of the plasma in a single shot. In order to obtain information coming from two directions: the θ and Z axis, it was installed a hollow electrode with a BK7 glass window at the front of a flat mirror oriented at 45 degrees respect to the z axis. This set up allows obtaining picture sets with a double image in each frame: one is a side view of the plasma and the other one is a front view. The ICC system was placed inside of a Faraday's Cage with the rest of the electronic devices (scopes, pulse delay generator, etc.) for avoiding electromagnetic interferences. The timing between the ICC and the plasma current was checked by comparison of the signal coming from a Rowgosky coil and the ICC monitor pulse output. Figure 2 shows a composition of eight pictures obtained in one shot around its corresponding scope signal showing the frames timing respect to the current temporal derivative dI/dt. This way of operation allows obtaining valuable information about the current sheath (CS) implosion process. The sequence showed in Figure 2 corresponds to a chamber dimension of 70 mm diameter by 100 mm long. The chamber dimension corresponds to the best CS initial radius in order to obtaining a good agreement between the maximum current and the stagnation point formation in the plasma column. Note in Figure 2 how the maximum compression ratio is reached at the same time of the maximum current.

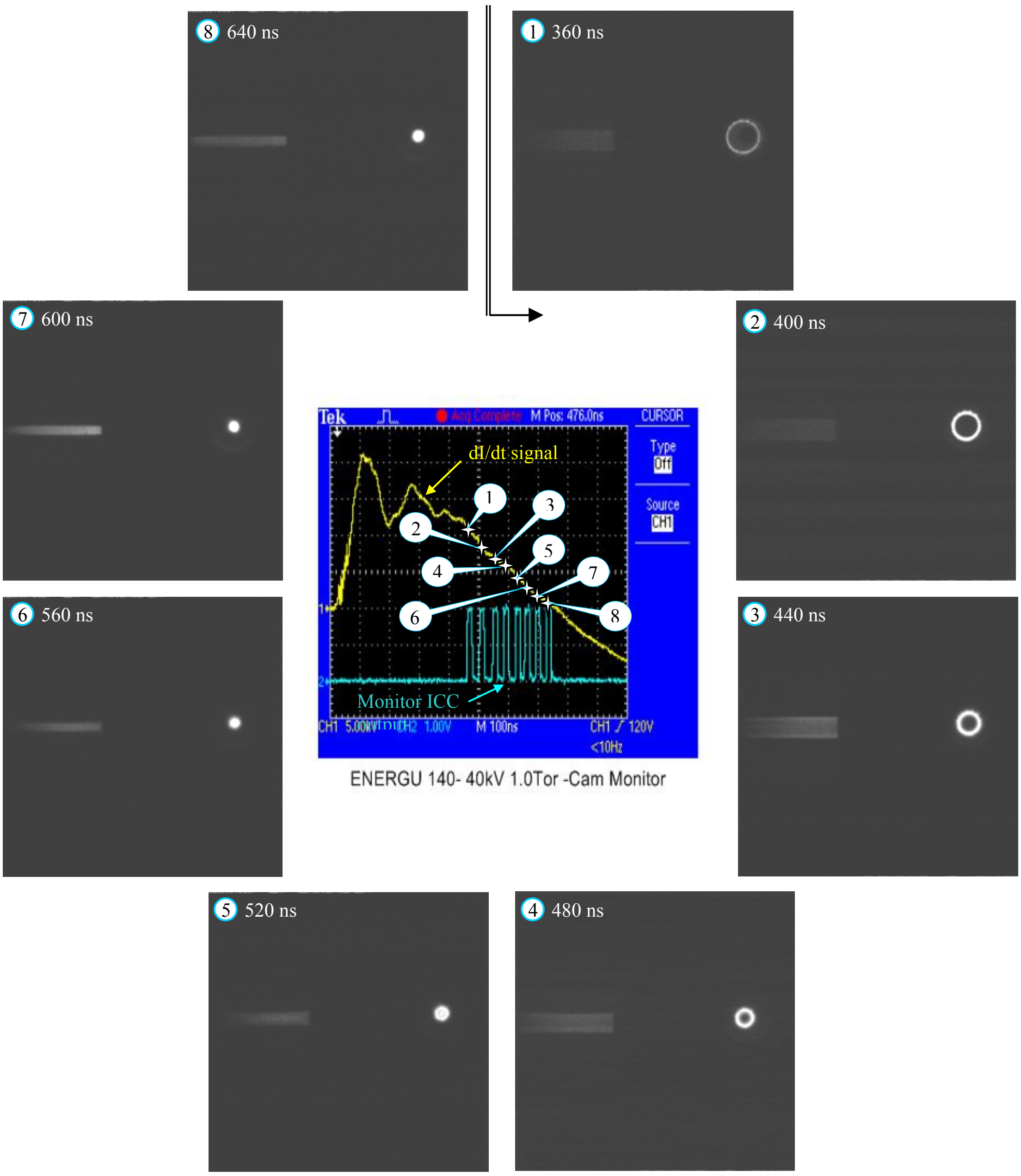


**FIGURE 2,** Side – Front simultaneous pictures and dI/dt signal vs ICC monitor pulses. $V_0 = 40$ kV, 1.0 torr, 5ns exposure time, 40 ns delay between pictures.

## NEUTRON YIELD

Measurements of neutron yield were made by using a Silver Activated Neutron Detector (SAND) developed by the National Physical Laboratory (UK). Operating with the 70 mm diamenter chamber, the neutral gas pressure was 0.5 torr and the distance between the middle of the plasma column and the SAND was 0.5 m. The signal is 5 times grater than background before firing the discharge. According to an initial calibration by Am-Be source a yield of approximately $10^7$ neutrons/shot was estimated.

## CONCLUSIONS

A new research facility in plasma physics and small nuclear fusion experiments is available in the University of Castilla-La Mancha in Spain. Research plans of the group include the study of R-T instabilities mitigation by means of neutral gas profile control by mean of gas puff operation and its influence in the nuclear fusion reaction yield. On the other hand, the device can be easily transformed in an exploding wire experiment by replacing the electrode system. This option opens the possibility to explode this device as a driver for an interesting x-ray source facility [4,5].

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