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# Dena, a new PF device

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**Abstract** In this paper we are going to introduce "Dena", a new Filippov type plasma focus facility, with a condenser bank of 0.288 mF, and a maximum supplying energy of 90 kJ (at $V_{max}$= 25 kV). The facility was installed and started to work in the first quarter of the year 2000. Major points of the paper are: – Dena's construction, functionality, and diagnostic system. – Preliminary results: Different modes of neutron, X-ray, and "hot spot" production, as well as the possibility of controlling operational mode, by changing anode configuration and initial discharge condition.

**Key words** Dena • focus • fusion • neutron • plasma • X-ray

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## Introduction

Dena is a new Filippov type plasma focus facility, constructed and built by the Plasmofo company. It was installed in Tehran in the first quarter of the year 2000.

One of the basic features of all plasma focus (PF) discharges, in both Filippov and Mather types is the behavior of the plasma-current sheath (PCS) in the stage of its radial compression. While in the Mather type facilities, the radial compression phase lasts a short time (compared with acceleration time in the inter-electrode gap), it becomes the main phase in the Filippov type. This leads to additional possibilities for variation of the PCS profile in the Filippov type facilities. As it was shown earlier [1, 3] modifying anode shape, makes it possible to affect the PCS, and from within the mode of the discharge.

Obtaining new data about the influence of anode shape and the composition of the working gas, on the discharge scenario, was one of the main goals of the first experiments on DENA.

## Apparatus

Principal circuit-diagram of Dena is shown in Fig. 1. The discharge system is a diode with the so-called "flat" geometry of electrodes. Anode is a disk of copper, with a diameter of 50 cm, and a relatively easy changed anode insert at its center. It is insulated from the cathode by a cylindrical porcelain insulator with a height of 12 cm, and a diameter of 48 cm.

Lateral wall of the cathode is made of stainless steel with 14 diagnostic ports, and an inner diameter of 71.5 cm. Upper cover of the cathode is a disk of duraluminum with a diameter of 75 cm. There is an orifice in the center of this cover, with an aperture with a diameter of 16 cm. This orifice, which is closed by a 3 mm thick and relatively easy changed limiter, can be used for hard X-ray extraction. Inside the chamber, parallel to the lateral wall and the upper cover, there is a copper liner, providing a separation between vacuum and electrical functions of the cathode. Chamber volume is about 61000 $cm^3$.

Energy source of the facility consists of 24×12 μF parallel coupled capacitors each with 40 nH inductance. Through HV low inductance cables, electrical energy transfers to the triggered spark-gap, and then to the anode of the system. Ignoring inductance of the spark gap, zero inductance [4] of the system becomes about 23 nH, where 18 nH is the inductance of the cables, 2 nH of the capacitor bank, and 3 nH of the chamber. Using ω = sqrt(1/LC) and minimum total inductance of 23 nH, the rise time (or quarter period) of discharge current becomes 4 μs. A 47 kJ bank energy (corresponding to 18 kV bank voltage), leads to 2 MA short circuit current ($I_{SC} = [2 W_0/L_0]^{1/2}$), and so the zero impedance of the system becomes 9 mΩ.

## Diagnostic system

The diagnostic system consists of a 4-channel PC-based DAS (Data Acquisition System) including two GPIB compatible oscilloscopes (each with a maximum resolution of 50 ns), and the followings:

- Semiconductor SXR detector: Using this system, and assuming a spherical and symmetric SXR emission, a rough estimation of soft X-ray flux can be done.
- HXR detector with a NaI-scintillator: This system is relatively slow and should be used in an accumulative mode. The output is just a relative measure of the HXR yield.
- Photo-multiplier with a fast plastic scintillator: This system can register neutron and HXR yield in time with a resolution of 5 ns.
- Soft X-ray pinhole camera: Pictures of this camera are a measure of the SXR yield.
- Current derivative probes: These are two coils, each with 20 turns and a diameter of about 2 mm. Both are installed close to the positive electrode of one of the capacitors. One is used for DAS triggering and the other for displaying discharge current derivative.
- Magnetic probe: To study the dynamics of plasma current sheath, a magnetic probe with a cross section of 0.1 $cm^2$ is available.
- Rogowski coil: This coil yields the total discharge current. It is a solenoid, with a major radius of 53 cm, 1115 turn, and a minor diameter of 1 cm.
- Neutron counter: This is a Geiger-Muller counter surrounded by an indium foil (0.23 mm thickness) and placed in a polyethylene moderator.

## Experiments

Finding optimal discharge conditions, and defining of the basic discharge parameters, were the main goals of the first experiments. Two types of anode inserts were used, a flat one made of copper, and a conic made of an alloy of copper-tungsten. With argon as filling gas and a bank voltage of 18 kV, maximum discharge current was 1.3 MA (dI/dt ≈ $2.8\times10^{11}$ A/s). Using a flat insert, the mean value of the rise times of 72 shots with different gases, and relatively high radiation yield, was 3.99±0.12 μs. With a conic insert, for 38 shots, this value became 4.27±0.22 μs. We could also change the mode of the operation by changing the anode insert. While the flat insert stimulates development of a pinch close to it's surface (favorable for HXR production), the conic one leads to higher and denser pinch (Fig. 2a, b). Using neon, conic insert led to 5 times more SXR yield than the flat insert. Conic insert also leads to enhanced neutron yield, and formation of more "hot spots" (Fig. 2c). Using $D_2$ + 2% Kr with a bank voltage of 18 kV, the maximum neutron yields became $0.5\times10^9$ in the case with the flat insert, and $3\times10^9$ with the conic insert. Similar values for 16 kV, were $0.5\times10^9$, and $2.4\times10^9$. Integral measurements of HXR yield was made with thermo-luminescent dosimeters (TLD) based on LiF. With neon, the flat insert and a bank voltage of 16 kV, the mean value of HXR yield from 9 shots was 3.4 R. Using $D_2$ + 2% Kr, the flat insert, and a voltage of about 18.5 kV, the mean value of HXR yield from 13 shots becomes 4.98 R. It should also be noted that TLDs were placed on the top of the chamber on the aluminum limiter.

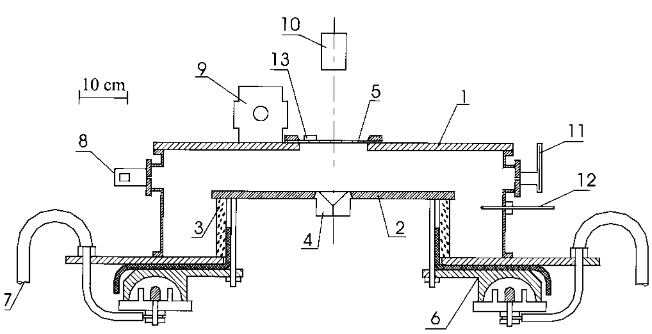


Fig. 1. Scheme of the DENA-facility: 1 – discharge chamber (cathode); 2 – anode; 3 – porcelain insulator; 4 – anode insert; 5 – Al limiter; 6 – vacuum spark-gap; 7 – cables; 8 – semiconductor detector (SXR); 9 – neutron detector (G-M counter); 10 – vacuum diode with NaI scintillator (HXR); 11 – pin-hole camera (SXR); 12 – magnetic probe; 13 – thermo-luminescent detector (TLD).

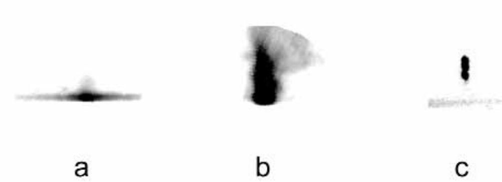


Fig. 2. Images obtained with the pinhole camera. The pinhole diameter was 1 mm. It was covered with a Be filter with a thickness of 10 μm. a. – flat insert, 0.6 Torr Ar; b. – conic insert, 0.85 Torr Ne; c. – conic insert, 1.4 Torr $D_2$ + 2% Kr.

Table 1. Mean value of optimal chamber pressure for different cases.

| Type of Gas | Type of Insert | $V_{Bank}$ (kV) | $P_{ch}$ (Torr) |
|---|---|---|---|
| $D_2$ + 2% Kr | Flat | 16 | 0.83 ± 0.07 |
| $D_2$ + 2% Kr | Flat | 18 | 1.01 ± 0.26 |
| $D_2$ + 2% Kr | Conic | 16 | 1.03 ± 0.18 |
| $D_2$ + 2% Kr | Conic | 18 | 1.26 ± 0.28 |

Optimal chamber pressure was different for different inserts. Each row of Table 1 shows the mean value of 15 chamber pressures all lead to relatively high yield.

## Summary

Investigations have shown that apart from the type (Filippov or Mather) of a PF, shape and material of the anode, can affect the yield [2, 3, 5]. However, there is less information about the extent of these effects, particularly for Filippov type facilities. The Dena is a new Filippov type PF device which makes it possible to carry out experiments at energy levels up to 58 kJ, e.g., by varying initial parameters (inclusive anode insert) different pinch scenarios can be studied. Using Dena, we could compare the influence of a flat anode insert made of copper, with a conic one made of an alloy of copper-tungsten. The conic insert led to higher pinch, and more hotspots. With $D_2$ + 2% Kr, it cause about 6 times more neutron yield. With neon, conic insert led to 5 times more SXR yield. Using conic insert, best yields were obtained with about 24% higher chamber pressure. It led to longer discharge current rise time too. While with the flat insert, rise time was about 3.99 μs, with the conic insert it became to about 4.27 μs.

We have also observed that using $D_2$ + 2% Kr leads to more neutron and hard X-ray yield than puffing only $D_2$. We do not know exactly what the reason is. This may be a subject for further investigations.

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