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PF-1000 device

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Abstract The paper presents the megajoule plasma focus facility operated at IPPLM. In order to study plasma focus (PF) discharges several diagnostics tools have been prepared. The preliminary observations of current sheath motion, as well as measurements of the current signals are reported.

Key words dense plasma • plasma focus • Z-pinch

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Introduction

Plasma focus (PF) machines are pulsed electrical discharges in gases where the dense and hot plasma is created. Development of the plasma current leading to formation of the dense plasma can be divided into three main phases. The first one is the initial gas breakdown and the formation of a correct current sheath. In the second phase, the sheath is formed and pushed by the Lorentz force toward the opening of the center electrode (anode). The third stage of the discharge is the rapid collapse of the current sheath toward the axis in a form of a dense plasma column (pinch). The propagation time from the breakdown to the pinch formation is a few microseconds. The pinch phase is much shorter, of the order of few tens of nanoseconds. In general sense, a plasma focus can be considered a power transformer: the energy stored as magnetic energy is abruptly converted into pinch plasma.

The first experiments were done with capacitor banks of a few tens kJ with a peak plasma current of about half a megaamper. Later, the scaling law as a function of the stored energy was investigated, particularly for neutrons. The large megajoule PF-1000 facility has been operated at the IPPLM for about four years and up to now the greatest efforts have been put into experimental studies dealing with the optimization of the device [3, 4]. In this paper we present the PF-1000 facility and the preliminary results of its investigations when this large Mather type electrodes operated at energy levels up to 800 kJ.

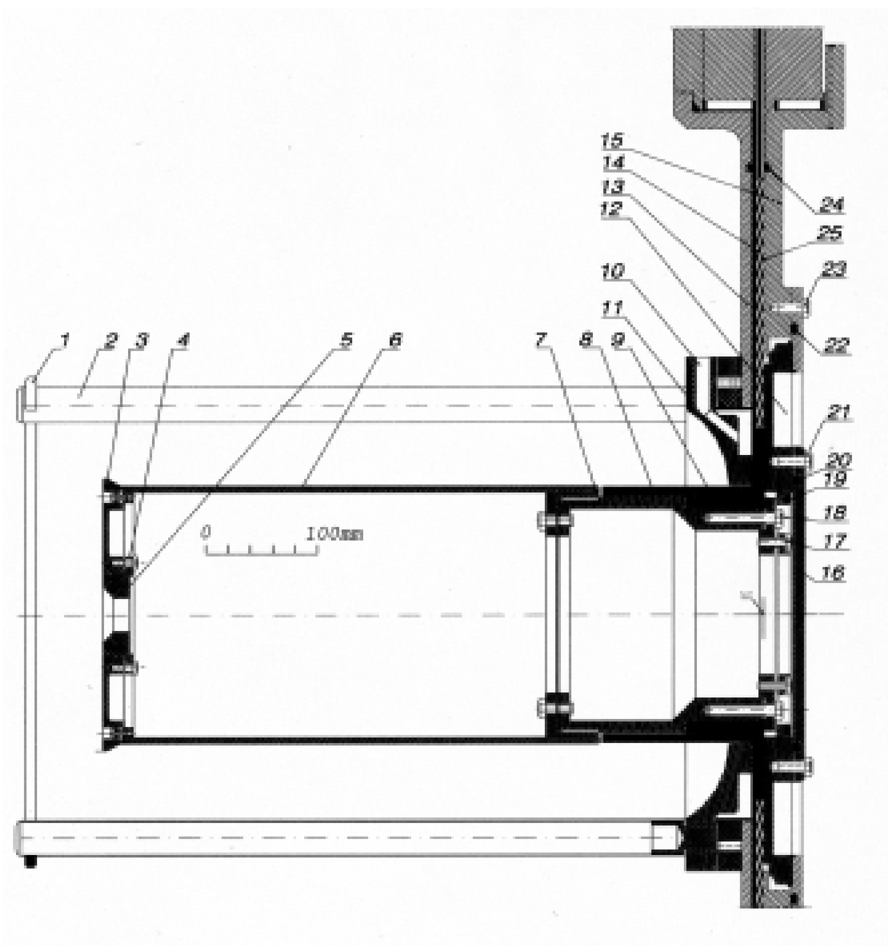

Fig. 1. Mather type electrodes of the PF-1000 plasma focus facility.
1 - Centering disk;
2 - Thin-walled tube;
3 - C.E. plate;
4 - Flange holder;
5 - Inset;
6 - Central electrode (C.E.) bush 1;
7 - C.E. bush 2;
8 - Alundum insulator;
9 - Teflon insulator;
10 - Ring for outer electrode (O.E.);
11 - Ring for C.E.;
12 - Small flange for C.E.;
13 - Flange for O.E.;
14 - Laminar insulator;
15 - Big flange for C.E.;
16 - C.E. lid;
17 - Screew M8×25;
18 - Screew M10×40;
19 - Flange holder for C.E.;
20 - Packing ring ∅ 8 mm;
21 - Screew M10×25;
22 - Packing ring ∅ 8 mm;
23 - Screew M12×25;
24 - Packing ring ∅ 8 mm;
25 - Insulating separator.

The apparatus

A plasma focus facility can be divided into three main units:

– the condenser bank and pulsed electrical power circuit driving the plasma discharge,
– the mechanical, vacuum and gas system consisting of the vacuum chamber, coaxial electrodes, vacuum and gas handling system,
– the data acquisition and diagnostics system.

Fig. 1 is a schematic diagram of the coaxial plasma focus apparatus. The design shown in Fig. 1 consists of two coaxial electrodes and an alumina insulator, across which the initial breakdown occurs. The outer electrode (OE) consist of 24 stainless steel rods. The rod diameter is 32 mm. The outer electrode (OE) and solid center electrode (CE) diameters are 200 and 115.5 mm, respectively, with CE length of 600 mm. The minimum annular spacing is $\delta r = 68.5$ mm. The OE is attached to a circular grounded cable header. The CE attaches to a central header that provides an electrical con-

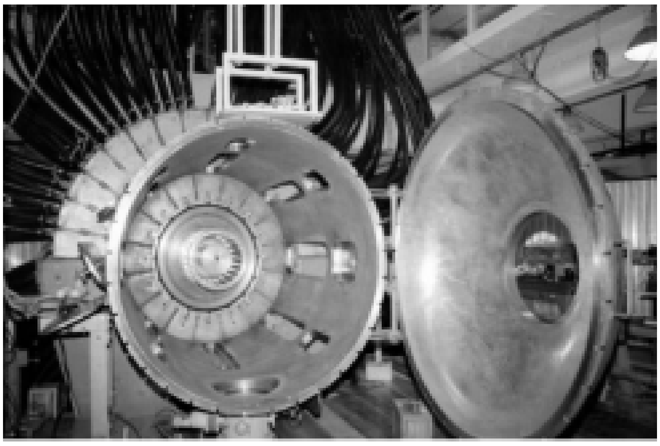

Fig. 2. The PF-1000 plasma focus facility.

Fig. 3. Condenser bank modules.

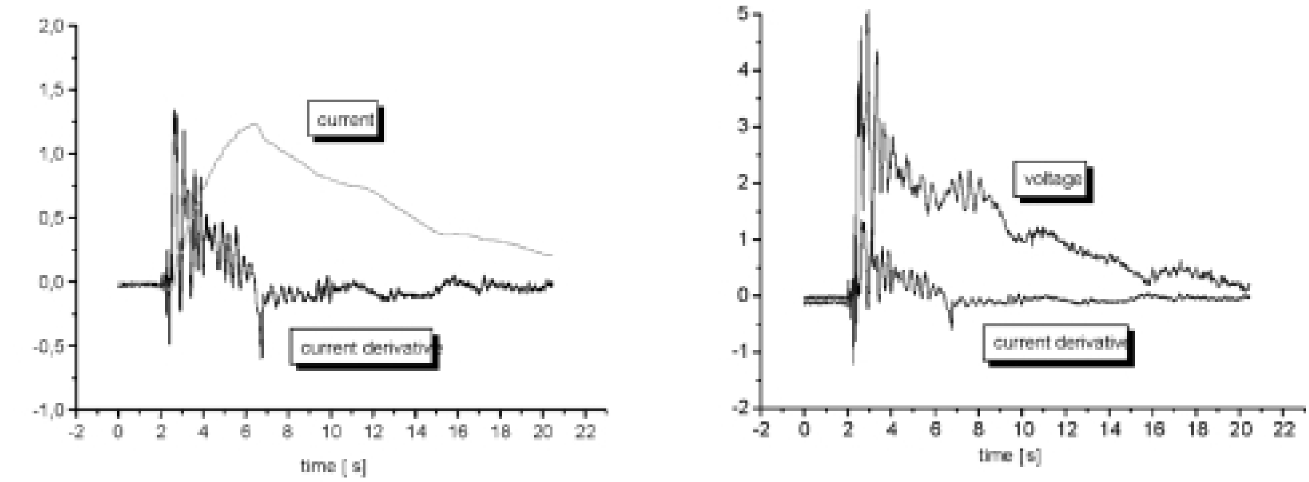

Fig. 4. Typical waveforms of the time derivative of the current, voltage, and current of the PF-1000 discharge.

nection and vacuum seal. The cylindrical alumina insulator sits on the CE (Fig. 1). The main part of the insulator extends – 113 mm along the CE into the vacuum chamber. This insulator prescribes the shape of the initial current sheath between the CE and the back plate of the OE.

The vacuum vessel of stainless steel surrounds the electrode structure (Fig. 2). The vacuum chamber has a large volume (1400 mm in diameter and 2500 mm in length). Ordinary vacuum technology, utilizing oil-diffusion pumps and anti-creep liquid N_2 traps is employed. The condenser bank of 1200 kJ, 40 kV system consists of twelve condenser modules each comprising twenty four 50 kV, 4.625 μF low inductance condensers connected in parallel (Fig. 3).

The electric energy is transferred to a collector and electrodes by means of low-inductance cables. The importance of low-inductance cables, condensers, and switches in power supply cannot be overstressed if the large tube currents are to be achieved.

Summarizing, parameters of the PF-1000 generator are:
- the charging voltage – $U_0 = 20 \div 40$ kV,
- the condenser bank capacitance – $C_0 = 1.332$ mF,
- the initial capacitor bank energy – $E_0 = 266 \div 1064$ kJ,
- the nominal inductance – $L_0 = 8.9$ nH,
- the quarter discharge time – $T_{1/4} = 5.4$ μs,
- the short-circuit current – $I_{SC} = 15$ MA,
- the characteristic impedance – $Z_0 = 2.6$ mΩ.

At present we start to work at 500 to 800 kJ energy levels and the experimental program concentrates on the training procedure and optimization of operational conditions. Up to now we have designed and put into operation several diagnostic system [1, 2].

Diagnostic systems

The basic diagnostics applied in the studies of any plasma focus device are usually measurements of a discharge current and a voltage drop across its electrodes. The discharge current of the plasma focus is measured using a Rogowski coil (total current) or a magnetic probe (localized current distribution). Resistive probes are used in many systems to measure a transient voltage during the plasma focus discharge, due to their ease of the installation and operation. Since it is not possible to connect the probe to measure the voltage drop across the plasma directly, this measurement is usually made externally across the electrodes of the device. The current, the time derivative of the current and voltage waveforms of typically plasma focus discharge registered on the PF-1000 device are shown in Fig. 4. The sharp voltage spike and current dip are characteristic for a focusing discharge in which a large increase of the plasma column impedance has occurred.

The plasma produced at the pinch phase of the plasma focus discharge is an intense source of radiation, including X-rays [1]. Hence, it is essential to incorporate the X-ray detection system in the PF device. At present, the time evolution of the X-ray emission from the plasma focus is obtained using a soft X-ray PIN diode. This type of X-ray detector is used for

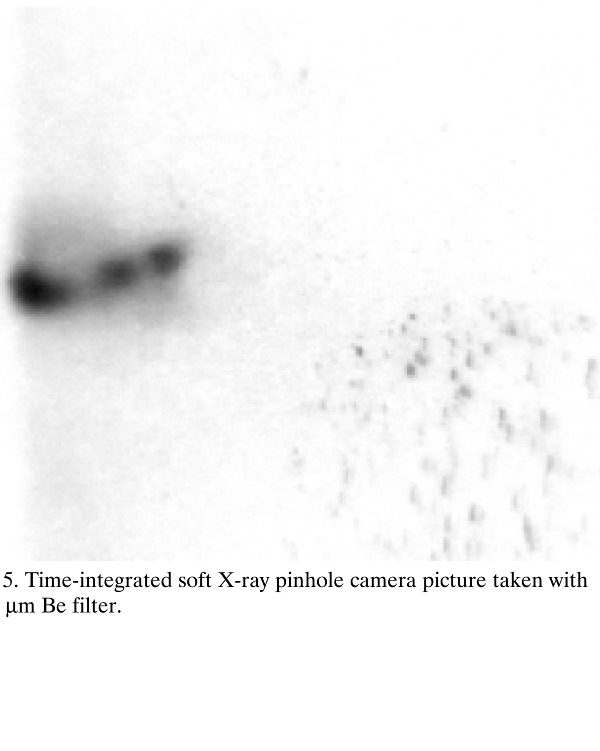

Fig. 5. Time-integrated soft X-ray pinhole camera picture taken with a 25 μm Be filter.

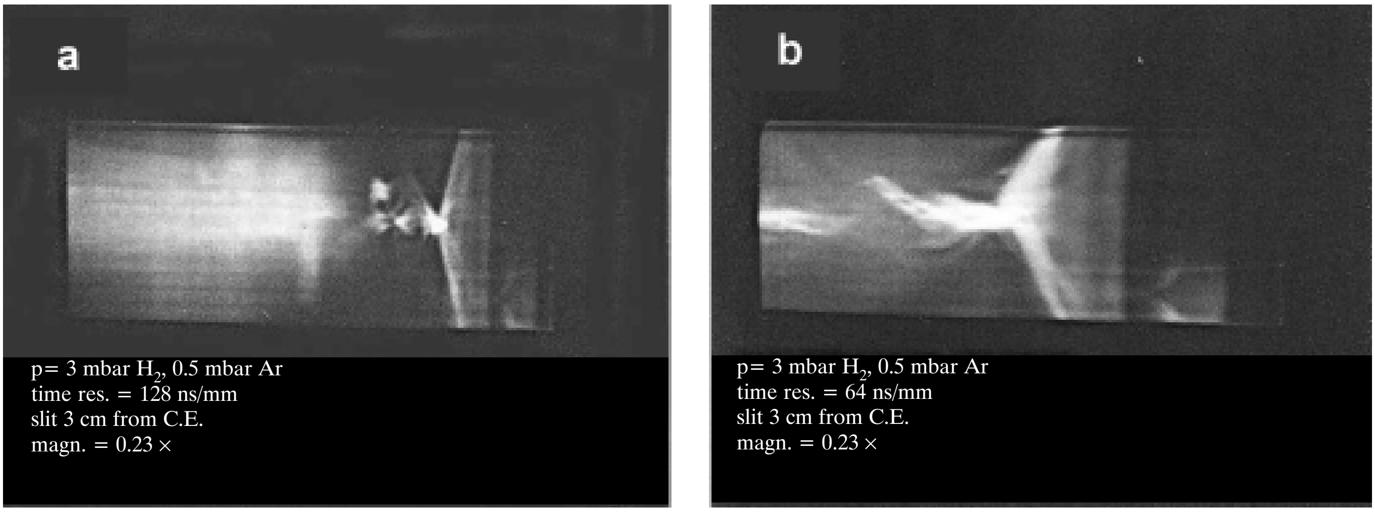

Fig. 6. Streak pictures of the collapsing current sheath, as registered in the PF-1000 under the same conditions.

wavelengths from 0.1 to 1 nm. Photomultipliers are generally used for hard X-rays with wavelengths shorter than 0.1 nm. We also register time-integrated images of the X-ray emitting region of the plasma focus, since this gives an indication of the size and shape of the plasma at pinch phase (Fig. 5).

Information about the dynamics of the plasma focus discharge can be obtained by means of a side – on monochromator – streak camera system. In the case of a "good" shot the implosion is very fast and the pinch is narrow (Fig. 6a). For each case two consecutive pinching events have been observed. In a "bad" shot, the implosion is slow and pinch radius is larger and diffused (Fig. 6b). These photos we obtained in the PF-1000 experiment with the following parameters: capacity of condenser bank C_0 = 1.332 mF, the initial charging voltage U_0 = 32.5 kV, the maximum discharge current I_0 = 1.5 MA and the current rise time was equal to t_0 = 8 μs. The discharge chamber was filled with a hydrogen + 14% argon mixture at the initial pressure p_0 = 3.4 hPa.

Remarks

The plasma focus installation, in the described configuration, offers the possibility of studying a number of phenomena without the need of the very fast capacitor banks that are required for purely cylindrical Z-pinch plasmas. The geometry of the device offers also very good possibilities for the simultaneous use of many diagnostic techniques which are essential to the comprehension of the phenomena occurring in the experiments.

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References

1. Abdallah J, Clark REH, Faenov AYa et al. (1999) Electron beam effects on the spectroscopy of multiply charged ions in plasma focus experiments. J Quant Spectrosc Rad Trans 62:85–96
2. Sadowski M, Szydlowski A, Scholz M, Kelly H, Marquez A, Lapone A (1999) Application of solid-state nuclear track detectors for studies of fast ion beams within PF-1000 and other plasma-focus facilities. Radiat Meas 31:185–190
3. Scholz M, Borowiecki M, Denus S et al. (1995) Investigation of the Plasma-Focus phenomena on the PF-1000 facility. In: Proc Int Symp PLASMA'95, Warsaw, Poland. 2:15–22
4. Scholz M, Karpinski L, Stepniewski W et al. (1999) Foam liner driven by a plasma focus current sheath. Phys Lett A 262:453–456