Comparative Characteristics of Four Small Dense Plasma Focus Devices

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Abstract. Four small (in the energy range 2-7 kJ) dense plasma focus devices were elaborated and put into operation in the last several years: ING-103, DPF-10, PF-5M, and DPF-6. Each device has its own parameters (energy, current rise-time and magnitude, pulse duration of ionizing radiation of different types, weight, etc.) and together with the specific discharge chambers they are optimized for various applications. Comparative description of functioning parameters of these devices together with the results of the most successful applications is presented in the report.

Keywords: Dense plasma focus, Deuterium, Tritium, Neutron yield, Surface damage.
PACS: 52.58.Lq, 52.59.Hq, 52.40.Hf.

INTRODUCTION

NX-1 installation destined to execution of the soft X-ray lithography study [1-2], which design was developed by authors of the report in collaboration with Nanyang Technological University, Singapore (1996-2000) is a prototype of the series of small-scale dense plasma focus (DPF) devices, described here.

Using gained experience as well as selected componentization of NX-1 device the neutron pulse generator ING-103 was developed as an output of small-batch production arranged at All-Russia Research Institute of Automatics (VNIIA) Moscow, Russia (http://www.vniia.ru).

Owing to the fact that Moscow Physical Society is able to combine into one the experience of scientists from different institutions three other small-scale DPF devices described here had been designed and are developed by the joined team of experts as a direct result of an activity in the context of IAEA Coordinated Research Projects named below.

COMPARATIVE CHARACTERISTICS OF THE DEVICES

1. Neutron Pulse Generator ING-103

The picture of ING-103 DPF device is shown in Fig. 1 (a). The main operation factors of the device are shown together in Table 1.

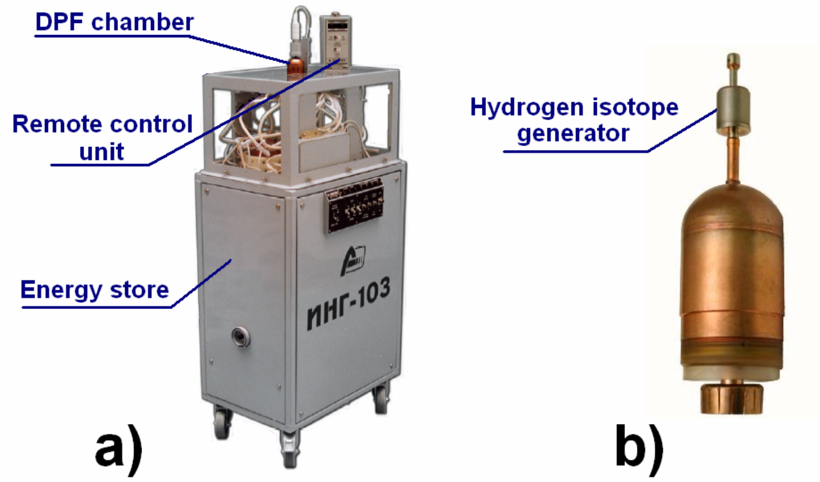

FIGURE 1. The photo of ING-103 neutron pulse generator (a); neutron DPF chamber (b).

TABLE 1. Main Characteristics of DPF 6.0 device.

Characteristic Name	Meaning
Battery Capacity	14 μF
Actuating Voltage	20 kV
Energy Storage	2.8 kJ
DPF Chamber Working Gas	D_2 or D_2+T_2 - mixture
Neutron Yield	(D-D neutrons) 10^8 neutron/pulse; (D-T neutrons) 10^{10} neutron/pulse
Neutron Pulse Duration	20 nsec
Rep Rate	Operation Conditions of Single Shots
Life-Time of DPF Systems	~ 10^5 shots

The generator is assembled with power module; so it is produced as a unit, fed from AC 220 V power system. DPF chamber is the replaceable part of the device. It is equipped with a special hydrogen isotope generator, which is a single whole with the chamber and is foolproof vacuum isolated. In that way ING-103 is reliable pollution-free device.

We are convinced that a portable powerful short-pulse neutron generator described is able to be very useful for the modern fusion research program. Such a device can be used as an instrument for the experimental evaluation of neutron flux distribution around the reactor expected as a product of fusion reaction inside the big fusion installation, such as ITER. It would be expedient to place the generator in the different points inside the reactor and carry out measurements from the very start of its practical construction. Extra short pulse duration irradiated by the neutron source in question, using time-of-flight method, takes the opportunity to collect full information *about direct as well as back-scattered neutron radiation background in the operative floor.*

2. DPF 6.0, DPF 10.0, and PF 10M devices

Comparative characteristics of three named small installations are presented in Table 2.

TABLE 2. The Characteristics of Three Small-Scale DPF Devices

Characteristic Name	DPF 6.0	DPF 10.0	PF 5M
Battery Capacity	28 μF	48 μF	16 μF
Actuating Voltage	15-20 kV	10-15 kV	15-20 kV
Energy Storage	3.1-5.6 kJ	2.4-5.4 kJ	1.8-3.2 kJ
DPF Chamber Working Gas	H_2, Ar, Xe, D_2, or D_2+T_2	H_2, Ar, Xe, D_2, or D_2+T_2	H_2, Ar, Xe, or He
Rep Rate	1-10 Hz (0.08 Hz is Realized Now)	Single Shots	Single Shots
Life-Time of DPF System	~ 10^6 shots	~ 10^4 shots	~ 10^4 shots
Place of Location	IPPLM Warsaw, Poland	ITEP Moscow, Russia	IMET Moscow, Russia
Project Start Date	December 2001	April 2003	December 2004

The current collector, which is the set of replaceable DPF chamber, equipped every described installation. Based on neutron DPF chamber design (see Fig. 1 (b)) we have designed a number of chamber constructions in order to bring the chamber to conformity with its special predestination. Consequently we had: neutron DPF chamber, soft X-ray DPF chamber, hard X-ray DPF chamber, water-cooling DPF chamber to operate in rep rate regime, etc.

As a matter of fact, specific construction of DPF chamber determines the application of the DPF device in general. So, using hard X-ray chamber we carried out the experiment of biological objects irradiation [3-4], with the aid of multipurpose DPF 6.0 device (Fig. 2). A number of other experiments were carried out on the device with an employment of other type of DPF chamber.

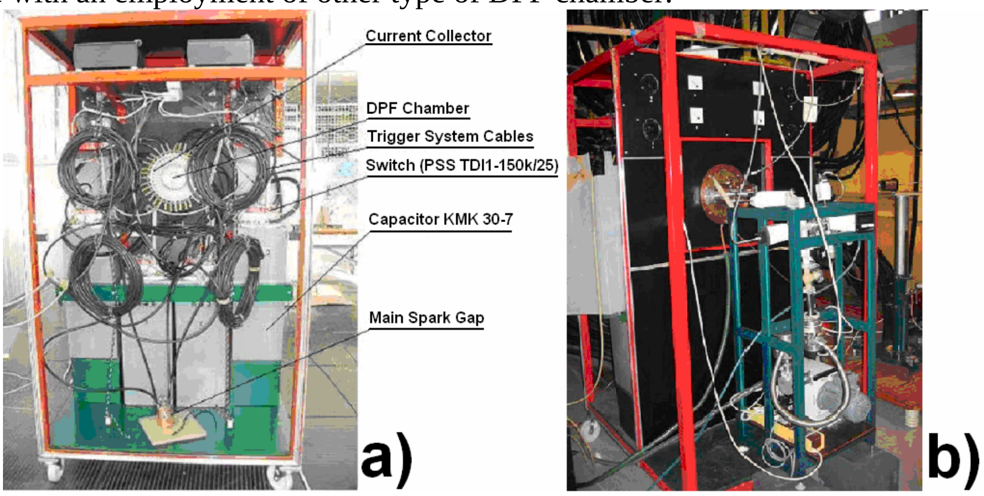

FIGURE 2. The photo of DPF 6.0 device: back (a); front face (b).

The DPF 10.0 device (Fig. 3) is planed to operate generally in neutron generator regime using neutron DPF chamber PF-7 (see Fig. 1 (b)). Rather big energy store of the device makes it possible to exceed neutron yield of D-T reaction of 10^{11} neutron/pulse if PF-9 chamber [5] will be employed.

In order to supply with the planed time-of-flight neutron measurements we have placed DPF 10.0 device into long room (see Fig. 3 (b)).

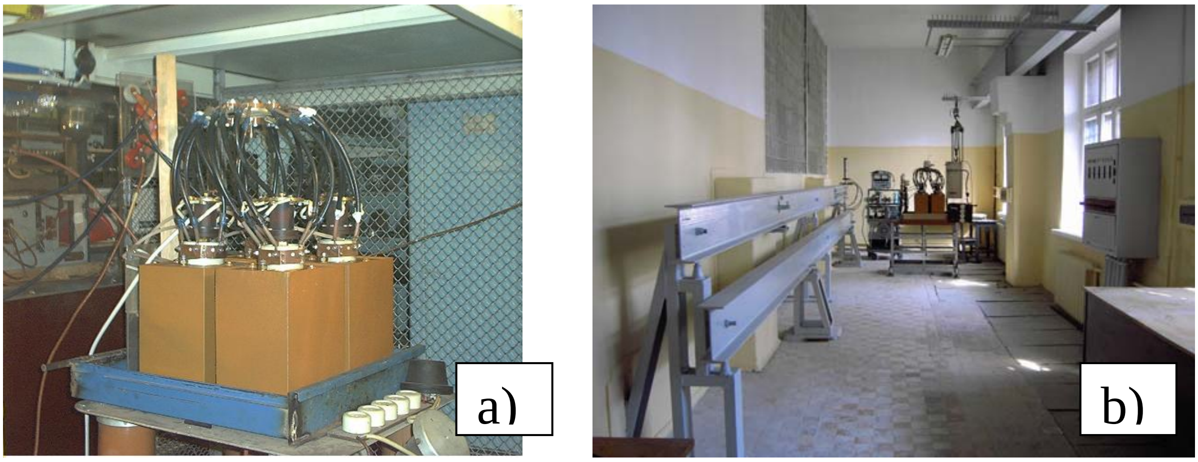

FIGURE 3. The photo of DPF 10.0 device at the place of testing (a); DPF 10.0 device (background scene) situated at the long room (b).

The PF 5M device was designed as an instrument for irradiation of any kinds of solid-state samples by powerful ion beam as well as hot dense plasma jet taking place within DPF chamber at the time of working discharge. It is possible to study plasma-surface phenomena by situating test sample inside DPF chamber on the different distance from the point of radiation beginnings (small spot near the central part of the negative electrode). Power density of ion flux and plasma jet close to the positive electrode surface amounts to 10^9 W/cm^2 falling down as increase of the distance.

Among the material science experiments, which we carried out using DPF devices (not just small-scale devices), the experiment relating directly to mainstream fusion program has been fulfilled last year [6]. Damages of carbon-tungsten samples, which were handed us by people from TOKAMAK program, under influence of deuterium ions and dense plasma streams within plasma-focus facility were studied.

Further testing of the materials for fusion program by means of DPF device as a source of powerful pulse radiation seams to be very promising.

The target unit, which makes it possible to irradiate test samples within DPF chamber, is shown in Fig. 4 (b).

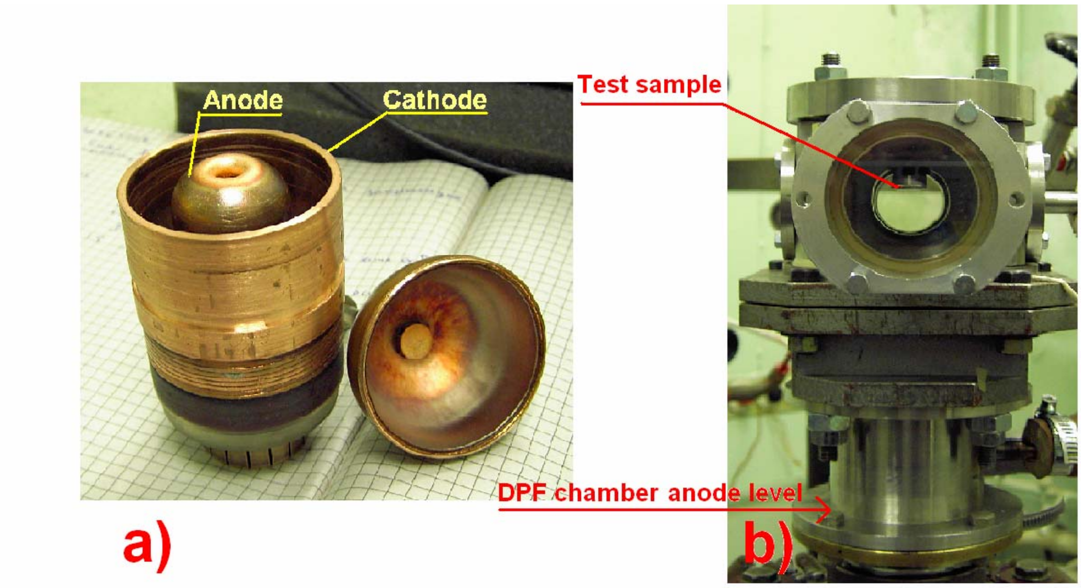

FIGURE 4. The photo of the DPF chamber, opened in order to take opportunity to connect target unit with the chamber (a); (b) the target unit with the test sample, connected to DPF chamber. PF 5M device

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