A STUDY ON EMISSION CHARACTERISTICS OF A PLASMA FOCUS IN THE DISCHARGE SYSTEM WITH A METAL-CERAMIC JUNCTION

N.I. Ajzatsky, A.N. Dovbnya, Eh.Yu. Khautiev[1], M.A. Krasnogolovets[2], V.I. Krauz[1], N.G. Reshetnyak, T.A. Semenets[2], Yu.Ya. Volkolupov[2], V.V. Zakutin
NSC KIPT, Kharkov, Ukraine
[1] RSC, Kurchatov Institute, Moscow, Russia
[2] KGTURE, Kharkov, Ukraine

PACS number: 29.17.+w

The high-current plasma-focus (PF) discharges are known to be the source of intense neutron radiation and X-rays in the quantum energy range from a few to hundreds of kiloelectronvolts.

As demonstrated in numerous experimental papers, with an increase of the power source energy above W ~100 kJ, the known power scaling for the neutron yield $N \sim W^2$, established empirically for the PF systems, is violated. This is mainly due to the fact that energy current flowing in the plasma pinch on the axis of the discharge system does not increase with W, and the part of the discharge current starts to flow at the periphery [1]. One of the factors preventing the overall current flow in the pinch lies in repeated breakdowns in the interelectrode gap [2] that shunt the principal current channel and cause the emission PF parameters to decrease. The instability of high-current impulsing discharges relative to repeated breakdowns is the fundamental property of these systems. The probability of repeated discharges grows with an increase in the energy put into the discharge. Therefore, their suppression presents a rather complicated problem. It has been established [2, 3] that the place of repeated breakdown formation is the insulator-inner electrode interface, because here a sharp electric-field gradient and a high specific heat release are concentrated.

To reduce the probability of repeated breakdowns of the interelectrode gap, we have developed and investigated a new design of the discharge system with a smoothed potential gradient at the juncture of the insulator and the inner electrode.

1 EXPERIMENTAL SETUP AND TECHNIQUES

The experiments were performed with the facility KPF-1M schematically shown in Fig. 1 at a stored energy W ~40 kJ (V ~25 kV, T/2~7 μs).

The discharge system comprises the inner electrode 4, 50 mm in diameter, along the entire length of which there is a through axial channel 5 ~14 mm in diameter; the outer electrode made as a squirrel cage, 100 mm in diameter, the electrodes, 200 mm in length. For comparison of results, two separable insulators of the same size and shape (each being a cylinder, 50 mm in diameter), made of Alundum 2 (Al_2O_3) and Alundum 2 with a metal-ceramic junction 3 (MCJ) at one of the ends, were used. The second insulator was produced by pressing jointly the powders of aluminum oxide and molybdenum so that the relative content of the metal varied from 0 to 100%. Correspondingly, the running conduction over a length of 30 mm smoothly varies. In this case, the electric field distribution gradient is smoothed off, and the density of thermal energy flow decreases at the initial part of the inner electrode due to the increased thickness of the skin layer and its increased area of contact on the current pick-off surface. The discharge system is placed inside the vacuum chamber 6, which, upon preevacuation to a pressure < 10^{-5} Torr, is filled with the working gas to a pressure from 1 to 10 Torr.

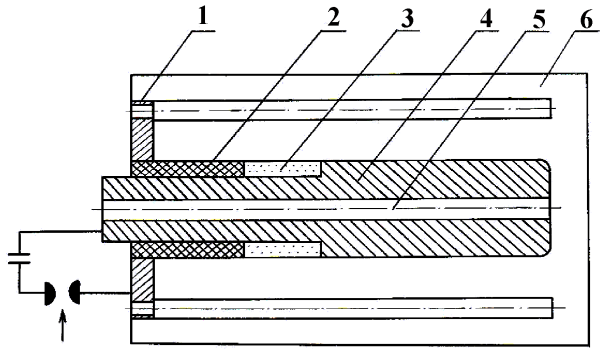

Fig. 1. The schematic of the facility KPF-1M.

Experiments were made to take measurements of voltage and discharge current, time and integral parameters of X-ray/neutron radiation. The pictures of the discharge were taken in the visible (moving-image camera) and X-ray (pinhole camera) spectral regions. The energy spectrum of ions accelerated in the PF was investigated using the magnetic analyzer described in ref. [4]. Nuclear photoemulsions were also used as a detector, providing the same energy resolution to determine the integral ion distribution pattern.

2 EXPERIMENTAL RESULTS AND DISCUSSION

The discharge dynamics and the PF formation were investigated for two types of the insulator. The moving-image camera photography of the discharge from both the end and the side has shown that in the case of the insulator with the MCJ, after the main plasma layer leaves the insulator, there is no glow observed at the juncture of the insulator and the inner electrode, whereas with the insulator without the MCJ the edge continues glowing practically throughout the discharge. The absence of a current flow at the above-mentioned juncture and of the corresponding arrival of ionized vapors to the interelectrode gap considerably increases the electrical strength of the initial part of the discharge volume. Higher thermophysical characteristics of molybdenum-base metal ceramics also positively contribute to a significant decrease of surface erosion. In particular, no sharp annular collar is formed, as is the case after several tens of discharges in the case of a usual insulator. It has been demonstrated in ref. [3] that, as this collar is formed at the juncture with the inner electrode, the reproducibility of high-parameter discharges decreases. From the comparison of current-voltage characteristics (Figs. 2 a and b) it follows that in the case of the insulator with the MCJ, the rise in the voltage at the moment of PF formation is greater in the amplitude and duration.

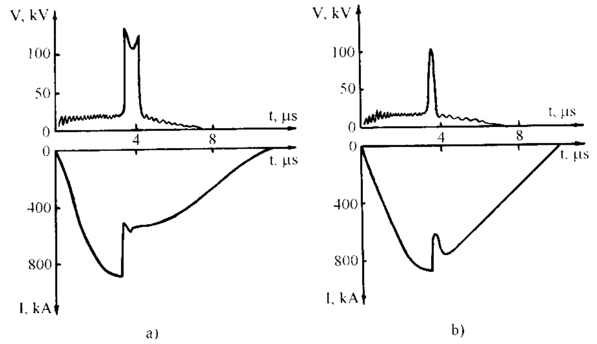

Fig. 2. Tipical waveforms of voltage (upper) and current (bottom) of the plasma focus discharge.

A deeper fall in the discharge current is observed, this points to a more efficient dissipation of the magnetic field energy.

At optimum conditions (W ~40 kJ, P ~6 Torr) the average neutron yield with a good reproducibility in a series of 60 discharges persists at a level of $\sim 10^{10}$ neutrons/discharge. A great number of discharges is characterized by the yield $\sim 1.5 \cdot 10^{10}$ neutrons/discharge, this being comparable with the value that corresponds to the scaling ($N \sim W^2$) for the given energetics. For the Alundum insulator without the MCJ the neutron yield is lower.

In the cases of using the insulator with the MC, when the neutron yield is close to scaling, the spectra of ion beams are of a discrete nature i.e., several bunches of nearly monoenergetic ions are observed (Fig. 3).

The first (X_1) and the second (X_2) pulses correspond to a hard X-ray radiation (HXR), and all the following pulses correspond to the ion beams bunches with different time-of-flight values. In the presence of the zero point of time counts (moment of generation of the given beam component in the PF) each of these oscillograms can be considered, after some correction, as an energy spectrum of accelerated ions. If one assumes that the acceleration of ions and electrons occurs in the same electric fields, then the HXR pulse length ≤ 50 ns is the criterion (pulse half-length is taken as a zero point), i.e., the time interval, within which the generation of all the beam components observed in the oscillogram takes place. The greater is the neutron yield, the higher is the beam intensity. The generation of the ≥ 0.8 MeV ions is practically always in synchronism with several great-amplitude HXR surges.

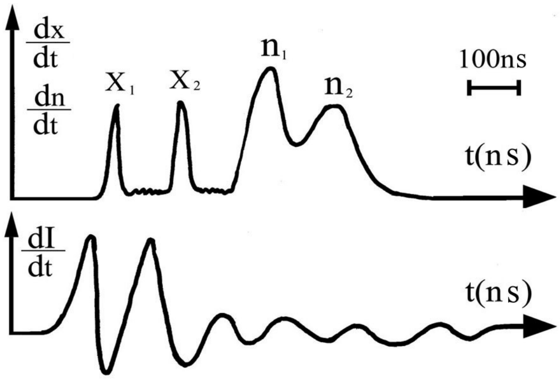

Fig. 3. Pulses of ion beams.

The surges of intense HXR registered in the experiment indicate that at a certain phase rather intense electron beams, along with ion beams, are formed in the PF. In this series of experiments the entrance to the axial channel in the inner electrode was closed by a ~15 mm thick copper insert, so that the electrode end became continuous. After 80 discharges a deep cavity, ~10 mm in diameter, was formed at the anode end under the action of the electron beam. The average energy of the main portion of electrons in the beam was estimated by the filter method to be between 30 and 60 keV.

The time-resolution registration of neutron radiation and X-rays has shown that in the case of using the insulator with the MCJ the discharges are mostly characterized by a multi-spike shape of pulses.

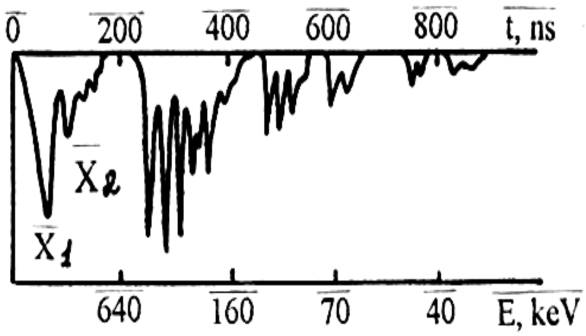

Fig. 4. Pulses from hard X-rays (X_1 and X_2) neutron radiation (n_1 and n_2).

Figure 4 shows the oscillograms of signals from the SNFT-3-type PMT with a scintillator detecting neutron radiation (n_1, n_2), X rays (X_1, X_2) separated in the time-of-flight R = 6.5.m, and also the discharge current derivative (dI/dt). The neutron (X-ray) pulse length ranges between 150 and 200 ns (40 to 50 ns) at half-maximum.

3 CONCLUSION

Experiments with a new-design discharge system including the MCJ between the anode and the insulator to decrease the electric field gradients in the initial part of the discharge volume were first made. The studies have shown a significant improvement in the conditions for the occurrence of the initial discharge phases. Parameters of ion/electron beams generated in the PF have been investigated. The ion beam is shown to consist of separate, nearly monoenergetic bunches in the energy range from 0.03 to 1 MeV.

REFERENCES

1. N.Openlander. Measurement of Magnetic Field and Current Density Distribution in the Frascati 1 mJ Plasma Focus Device // *Com. Naz. Nucl. Center Frascati Pap*. 1978, N 6, p. 1-17.
2. V.I.Krauz. *An experimental research of structures in a plasma-focus discharge*. A thesis abstract submitted for the degree of a Candidate of Physical-Mathematical Sciences, Kharkov, 1988, p. 14 (in Russian).
3. R.G.Salukvadze, S.P.Lalykin, Eh.Yu.Khautiev et al. *A device for plasma generation*. Authorship Certificate N 1369658, MKI N 05 N 1/00, N 3935280. Application 30.07.85.
4. V.I.Krauz, R.G.Salukvadze, Eh.Yu.Khautiev. Energy spectra of ion beams generated in the plasma focus // *Fizika Plazmy*. 1985, v. 11, is. 3, p. 281-287 (in Russian).