Source of radiation for radiography of high-speed processes on the basis of a "plasma focus" chamber (PF). PF chamber with ceramic electrodes.

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Two clearly defined modes can be observed in the course of operation of the PF chamber with deuterium:

- neutron radiation and very soft x-radiation, being slightly delayed by the chamber walls, can be observed at the gas pressure higher than 10 torr.
- intense bremsstrahlung with hardness of hundreds of keV (the neutrons are present as well but in a smaller amount) can be observed at the pressures of 0,1-5 torr; herewith, intensity and hardness of radiation increase as the pressure drops. The increase is limited by the time of discharge travel along the electrodes. This time appears to be so small that the current in the chamber does not have a chance to rise up to its maximum value.

In our case intensity and hardness of the observed radiation turned out to be so high that the applied detectors on the basis of multipliers maxed out when located in the most distant corners of the laboratory room (~ 15 meters). The NaJ crystal installed in the chamber flared like a flashlamp. The radiation observed suggested that we should try using plasma focus as the source for radiography of the fast processes, and, in particular, for a determination of the liners' boundaries in the electrophysical experiments. During radiography of the low-density objects there is a problem of their recording against the background of a thick optically dense barrier. To get a contrast image, one needs a big amount of relatively soft radiation (~ 100 keV). The standard x-ray units for 100 keV rated at the maximum possible radiation dose are made with single-shot exploding needle-shaped anodes.

The PF radiation (~ 10-20 keV) has already been used for radiography [1].

The goal of this paper will be to characterize the observed source of radiation with regard for parameters important for radiography, and, mainly, to propose the ways of its enhancement.

We have mentioned earlier that a too fast travel of discharge along the electrodes under low gas pressure represents a problem. The only available way to increase time is to increase the dimensions of the chamber; however, at this we face the problem of preserving the scenario of discharge evolution in the chamber. Our suggestion was to replace some electrodes in the chamber by the insulator – ceramics; the only metal parts will be the parts immediately adjacent to input insulator. The discharge pinched to the surface of ceramic insulators by magnetic field will be the conductor along which the current flows. The dielectric electrodes allow us manufacturing the electrodes of required length and setting the minimum inter-electrode gaps; herewith, a stable and exactly localized in space start of gas discharge (at the chamber input) is guaranteed. Curiously, a possibility appears to place some object in the vicinity of the focusing zone, for example, a solid target for ion bombardment without disturbance of the PF operation scenario.

Comparative discharges were realized in the ceramic chamber and in its metal copy to check the operability of ceramic electrodes.

A guaranteed absence of the start discharge from the ceramic part of the electrode surface gives freedom in choosing the length of ceramic electrode that will make it possible to coordinate the operation of the chamber with different sources at required pressure of the working gas.

The ceramic insert joins the operation of the chamber at the moment the current shell goes from copper over to ceramics. Under the effect of magnetic field the shell is elongated and pressed to the surface of a dielectric, as if it is spread on it. The discharge H-pinched to the dielectric surface becomes the conductor providing the current flow through anode.

To test the working capacity of the PF chamber with dielectric electrodes, a series of comparative experiments was carried out at the current to 0,8 MA with a ceramic insert in the chamber anode and with its metal copy. The experiments were realized at the capacitor facility “MODULE” with CCB= 36 μF, at the charge voltage of U0= 0 - 50 kV and half-period of T1/2 =1,5 μs.

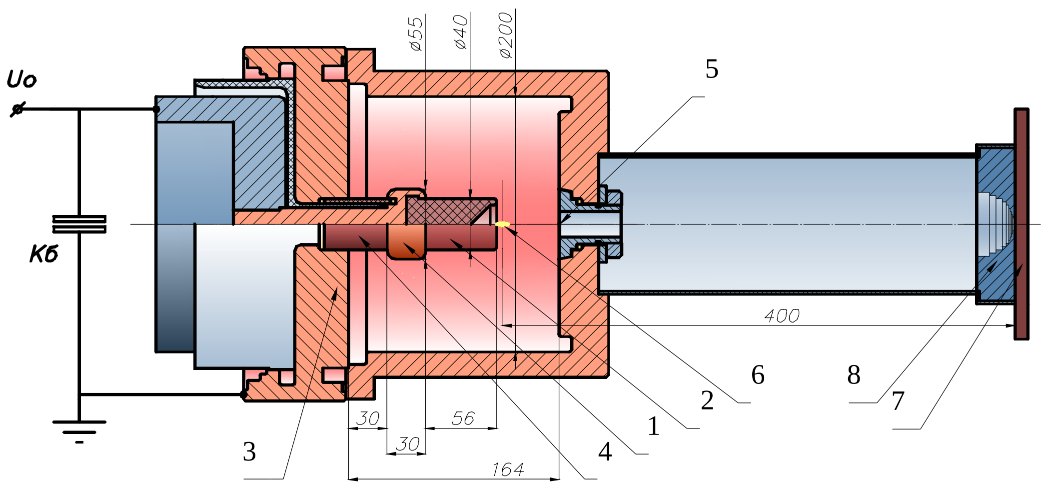

Figure 1. Scheme of the PF and location of the X-ray cassette behind the stepped lead filter.

Copper anode 1 with ceramic insert 2 is separated from cathode 3 (outer case) by ceramic insulator 4. A tight aluminum window 5 1 mm thick has been placed in the case along the pinching axis in the direction of recording. At the distance of 400 mm from the place of discharge pinching 6 a cassette with the x-ray film 7 has been placed behind lead stepped filter 8 with a 1 mm step.

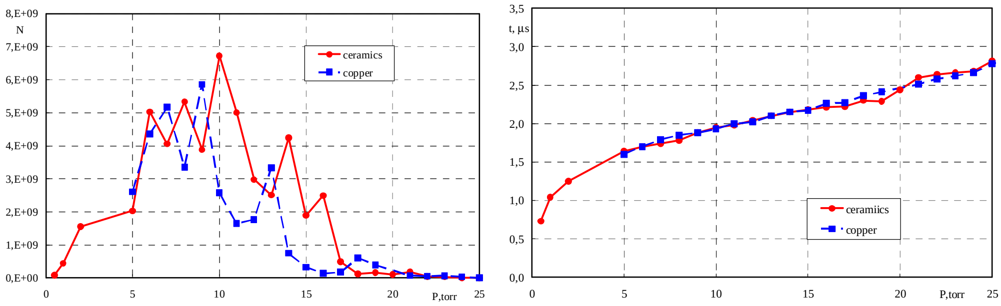

Figure 2. Neutron yield and time of discharge evolution vs. gas pressure in the chamber

The pressure dependence of neutron yield and the time of current-plasma shell motion from beginning of current flow in the chamber till focusing of the shell was determined. This plots is presented in Figure 2.

We can assert that the chamber with ceramic electrodes behaves almost identically to its metal copy.

Most of the charges in this work have been conducted with deuterium, however, the best results, from the viewpoint of hard X-rays generation, have been obtained with helium under pressure of 2 torr.

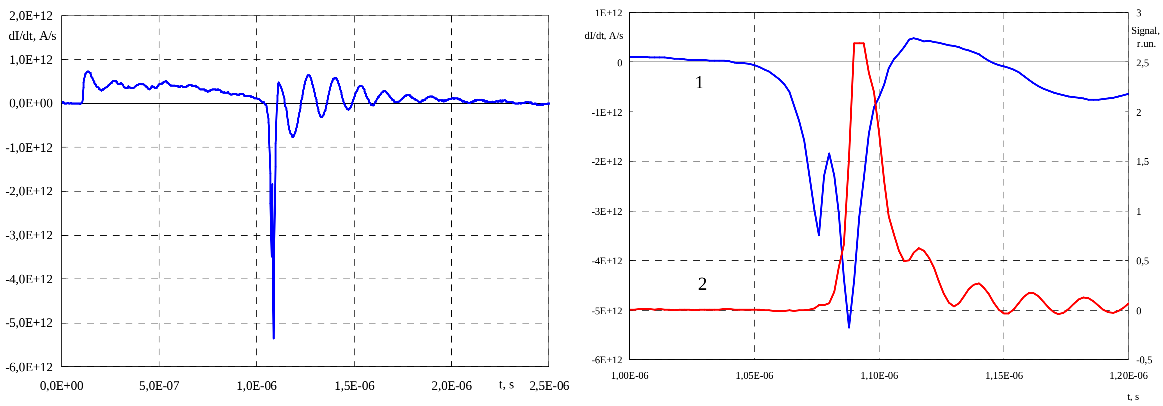

Figure 3. Current derivative and intensity of radiation of X-ray source in common time scale

Duration of the x-ray signal at half-height is ~10 ns that agrees with duration of pulse characteristics of the sensor. Hardness ~ 100keV.

Fragment of the obtained radiographic image with designation of materials and characteristic dimensions is presented in Figure 4.

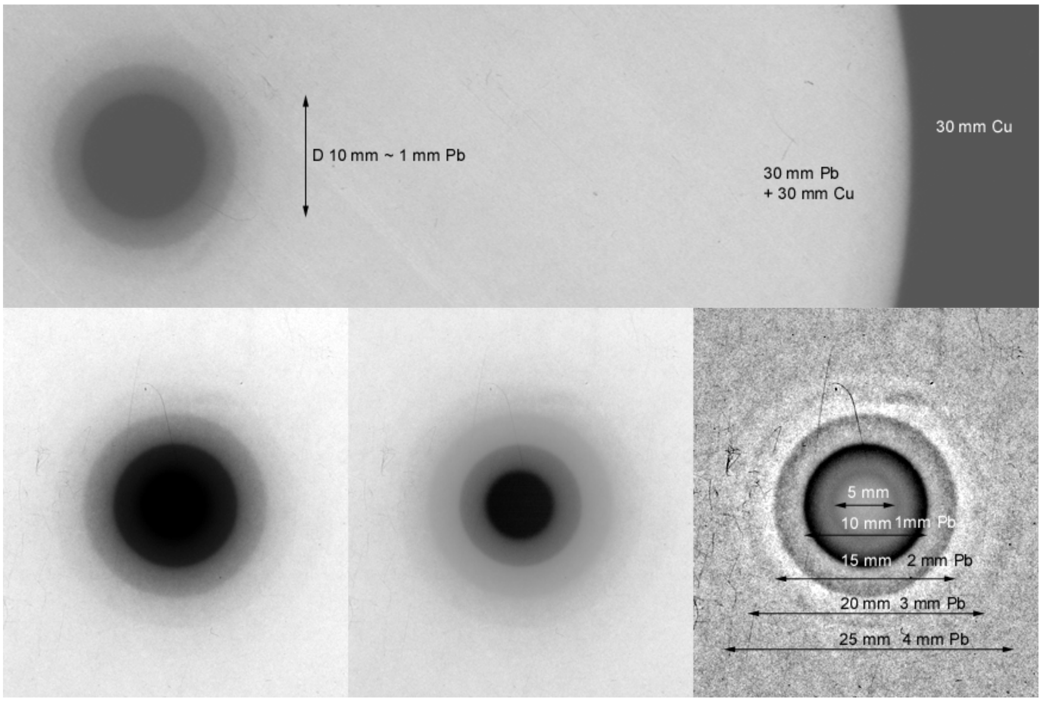

Figure 4. Processed image: a - original; b and c – processed with displayed boundaries

In some discharges a target (a tantalum disk ∅10×1mm) has been installed into the deepening of the anode closely to expected focusing zone. After several shots the chamber has been disassembled. A burnt through hole of ~1 mm diameter has been discovered in the center of a tantalum disk.

P.S. As a rule, the devices with the PF chamber are associated with capacitor facilities having big dimensions. However, there is a class of really compact sources of electric energy able to work for the PF chamber. Helical explosive magnetic generators HEMG [2] are comparable or even smaller in size than the PF chamber itself and therewith provide the required supply modes. HEMG is a transportable single-shot explosive source of energy. The use of the PF powered by HEMG allows obtaining the image of the object under study in the explosive electrophysical experiment. If it is necessary to protect the device from the action of HEMG explosion, it can be placed into the blast-proof container.

References

[1] Barmasov V.A., Makeev N.G., Rumyantsev V.G., Tsukerman V.A., Cheremukhin G.N. “Use of chambers with plasma focus for radiography of high-speed phenomena in gas”. In the book: “Physics and technology of pulsed sources of ionized radiation for high-speed processes study”, Sarov, RFNC-VNIIEF, 1996, pp.317-321.

[2] Sakharov A.D. Explosive magnetic generators. UFN. 1966. V. 88 № 4. P. 725 – 734.