Determination of the region of neutron generation in bubble chambers with a plasma focus

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The region of neutron generation in a bubble chamber with a plasma focus was measured by means of a raster technique and a pinhole camera. A high-efficiency bubble chamber with high spatial resolution was used to obtain the neutron-diffraction patterns in the basic measurements. The diameter of the neutron source was 2 mm and its length along the chamber axis was 5–12 mm.

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Many years of systematic studies of plasma-focus (PF) discharges, which were begun by the Filippovs,[1] have given detailed information on the space-time energy storage and on the plasma parameters at the focus.[2] However, the mechanism of neutron generation in such sources has not been adequately investigated.

The existing hypotheses of neutron generation at the PF (the model of a moving "thermonuclear reactor", ion acceleration, etc.[2–4]) predict different time, spectral, and especially spatial characteristics of neutron radiation. Knowledge of the dimensions, shape, and location of the region in which the neutrons are produced is very important for the determination of the contribution of a given mechanism.

According to the data obtained in different experiments,[5–7] the dimensions of the region of neutron generation differ drastically (diameter of 10–50 mm and length of 50–300 mm). Because of the low detection efficiency and comparatively low yield of neutrons, their density distribution in the source was generally measured during several discharges with inadequate spatial resolution.

In 1976, we have investigated the dimensions of the neutron source at a PF by means of a multislit collimator (raster) consisting of parallel plastic plates (the raster spacing was 2 mm, the plate thickness was 1 mm, and its length was 150 mm). The

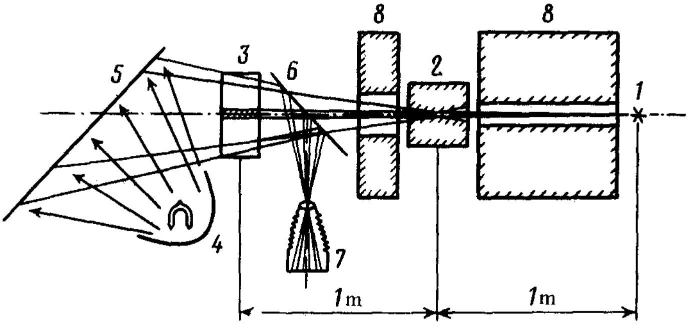

FIG. 1. Experimental setup. 1, Plasma focus; 2, collimator; 3, bubble chamber; 4, flash lamp; 5, diffuse reflector; 6, mirror; 7, camera; 8, shielding screens.

raster was placed close to the chamber. The neutrons were recorded on a RT-2 film with two thin scintillation converters. This method made it possible to roughly estimate after one discharge the dimensions of the neutron-generation region (diameter of 2–4 mm and length of 8–12 mm) and the location of its center of mass in the interelectrode space ($\sim$12 mm from the anode).

We briefly describe in this paper an experiment in which we obtained a completely satisfactory image of the neutron-generation region at the PF by using a bubble chamber (BC) as a high-efficiency detector of neutron-diffraction patterns.

The image was obtained in the following manner (Fig. 1). The neutron beam from the PF (1), which was transmitted through a conical opening of the collimator (2) with a 1-mm minimum diameter, formed a conical column of bubbles along the axis of the cylindrical volume of the BC (3) that was bounded at the ends by plane-parallel viewing windows. The total bubble density was proportional to the neutron-flux density. The chamber volume was illuminated by a flash lamp (4) through a diffuse reflector (5) and photographed by a camera (7) through the mirror (6). The geometry of the transmitted-light photograph was chosen in such a way that the bubble track of each neutron was projected to a point on the photographic film. The image on the film in this case corresponded to the density distribution of the neutron radiation with an accuracy determined by the spatial resolution of the collimator and the properties of the film. The shielding screens (8) were used to decrease the background level. The neutron-generation region of the PF was photographed in two directions: 1) along the chamber axis (Fig. 2a) and 2) along the normal to the axis (Fig. 2b) at a 1:1 scale. The dark ring on the photographs corresponds to the rim of the BC viewing window (ϕ 48 mm). The dark region near the center of the circle is the image of the neutron-radiation region. The cross-sectional dimensions of the emitting region (taking into account the size of the collimator aperture) did not exceed 2 mm and the length along the axis varied within the limits of 5 to 12 mm, depedning on the discharge mode. The center of mass of the emitting region was located on the chamber axis 12 mm from the anode. The weaker contrast of the photographs taken from the side is attributable to a lower neutron-flux density at the same background level. The yield of DD neutron in the photographs varied from 5×10^{8} to 5×10^{10} neutrons/pulse.

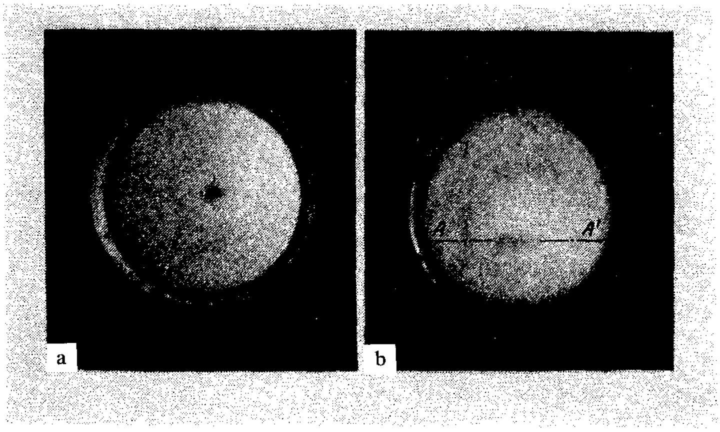

FIG. 2. Neutron diffraction patterns of the emitting region. (a) View along the chamber axis, (b) side view (AA' is the axis of the gas-discharge chamber; the anode is on the right-hand side).

In addition, the BC was used in experiments with the raster described above. Only the 1-mm-wide slit of the raster is sharply defined in the neutron-diffraction pattern. Neutron-diffraction patterns were also obtained of a copper cylinder whose length along the neutron beam was 400 mm. The image of the cylinder edge was not blurred because of small dimensions of the neutron source and low radiation density outside it. According to the estimates, the neutron yield from the diffuse region surrounding the source does not exceed 10% of the total yield. Note that the efficiency of the BC as a recorder of the neutron image is high ($\sim$50% for DD neutrons). A satisfactory image quality was obtained for a minimum neutron-flux density of 2×10^3 neutrons/cm^2 in the plane of the BC window.

Thus, the neutron diffraction photographs obtained in the bubble chamber made it possible to establish with high certainty that the region of neutron generation, which has an elongated axisymmetric shape with small dimensions, is spatially separated from the electrodes of the gas-discharge chamber. The neutron-radiation density decreases sharply outside this region and the main neutron yield (more than 90%) is apparently due to the processes occurring in the maximum compression phase of the plasma. It is interesting to note that the region of neutron generation coincides only partially with that of soft x-radiation generation, which was previously investigated in a similar chamber.[8]

The high neutron recording efficiency, the transfer linearity of radiation-flux density and the excellent spatial resolution of the bubble chamber make it possible to investigate in greater detail the neutron-generation region in plasma focus discharges.

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