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ELECTRONS CAUSING THE HARD X-RADIATION OF POWERFUL PULSED DISCHARGES

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As is known [(1)], a powerful pulsed discharge in a gas, in a certain range of pressures, is a source of hard X-radiation. In discharges in light gases, the energy of the X-ray quanta proves to be considerably greater than that which electrons can acquire in passing through the full potential difference applied at the corresponding instant of time to the electrodes of the discharge chamber. In a discharge in deuterium, a powerful pulsed discharge is also accompanied by the emission of neutrons [(2)]. In the work [(3)] it was shown that the boundary of the energy spectrum of hard X-rays arising in a discharge in hydrogen is 300–350 keV. In the same article, the experimental data known at present that relate to neutron and X-radiation of powerful discharges in deuterium and hydrogen are compared. The experimental facts convincingly indicate a common nature of the neutron and X-radiation. It was also pointed out that hard radiation apparently arises as a result of the acceleration of charged particles in electric fields directed along the axis of the discharge chamber. Such electric fields can arise during redistribution of currents in the process of change of the radius of the discharge column and in the case of the manifestation of certain types of instability. The present work is devoted to measuring the energy of the electrons responsible for the emission of hard X-ray quanta.

The discharge was carried out in a porcelain chamber 175 mm in diameter and 1000 mm high. The discharge circuit consisted of a capacitor bank of capacitance 36 μF, connected through a spark gap to the porcelain chamber. The maximum value of the discharge current, at an initial voltage on the capacitor bank equal to 40 kV, reached 200 kA. The experiments were carried out at an initial hydrogen pressure of $6 \cdot 10^{-2}$ mm Hg. This pressure corresponds to the maximum yield of hard X-ray quanta.

During the work, the presence of X-ray pulses was monitored with a scintillation recorder with output to a pulsed oscilloscope.

In accordance with the assumption concerning acceleration of electrons along the axis of the discharge chamber, an aperture was made at the center of the elec-

Fig. 1

Figure 1: Fig. 1

trode which, at the moment the voltage was applied, was at positive potential; the aperture was covered with aluminum foil 6 μ thick. Behind the aluminum window there was a flat vacuum chamber placed between the poles of an electromagnet powered from a storage battery. Hypersensitized X-ray photographic plates, manufactured at the Scientific-Research Institute of Motion-Picture and Photographic Materials, were used to record the electrons.

When a slit diaphragm was present between the aluminum foil and the photographic plate, in the absence of a magnetic field a sharp image of the slit appeared upon exposure of the plate by 5–10 discharges. When a weak magnetic field of ~ 20 oersted was applied, one edge of the image of the slit became blurred. This blurring could be explained only by the incidence on the plate

negatively charged particles. The observed blackening could not have been caused by penetrating electrons with an energy of $\sim$ 40 keV, arising at the moment of discharge initiation ([4]), since when the initial hydrogen pressure was reduced to $1.5 \cdot 10^{-2}$ mm Hg, when the intensity of the initial X-radiation sharply increases, and pulses of hard X-radiation were not observed on the oscillograph, there was no blackening of the photographic plate. The facts presented undoubtedly indicate that the electrons responsible for the occurrence of hard X-radiation are accelerated along the axis of the discharge.

Fig. 1. Microphotogram of the electron spectrum and of the reference line, corresponding to an exposure of 90 discharges

To determine the energy of these electrons, the photographic plate was exposed in the absence of a magnetic field, and then, without changing the photographic plate, several tens of discharges were produced in a field $H = 230$ Oe. This procedure made it possible to obtain on one and the same plate a blackening corresponding to the energy spectrum of the electrons, and a line corresponding to the undeflected beam of electrons. This line served to determine the position of the photographic plate in the spectrograph. The plates obtained in this way were photometered on an MF-4 microphotometer. A typical microphotogram is shown in Fig. 1.

To obtain the dispersion curve of the spectrograph, a graphical construction of electron trajectories was carried out. The construction of electron trajectories required a careful study of the topography of the magnetic field. Using the dispersion curve and measuring on the microphotogram the distance between the reference line and the boundary of the blackening caused by electrons deflected in the magnetic field, it is not difficult to obtain the value of the maximum energy acquired by the electrons when moving along the axis of the discharge.

As was indicated ([3]), the energy-spectrum curve of hard X-rays falls off sharply toward higher energies. Therefore one could expect that the position of the boundary of the energy spectrum of the electrons causing the hard X-radiation would depend on the exposure. To verify this assumption, a series of experiments was carried out in which the exposure was varied from 20 to 90 discharges. Comparison of the corresponding microphotograms showed that, beginning with an exposure equal to 50 discharges, the boundary of blackening ceases to shift toward the reference line (i.e., toward higher electron energies). It should be noted, however, that as the exposure is increased the blackening curve ···

near the boundary becomes less steep, which facilitates determination of the maximum energy. Processing of the experimental material obtained showed that the maximum electron energy is 300 keV.

To check the correctness of the construction of the electron trajectories, an electron beam with an energy of 100 keV was used. The electron source was placed inside the porcelain chamber, with the geometry of the experiment fully corresponding to the geometry of the experiments described here. The electron energy obtained from measurement of the potential difference agrees with the energy obtained from construction of the dispersion curve to an accuracy of up to 3%. Taking into account the scatter in the results of individual experiments, the authors believe that the accuracy of the results obtained is 5–6%.

Thus, direct experiments have shown that the electrons responsible for the occurrence of the hard X-ray radiation accompanying a powerful pulsed discharge in hydrogen are accelerated along the axis of the discharge chamber. The maximum registered electron energy is 300 ± 20 keV, which is in good agreement with the results of measuring the limiting energy of the X-ray spectrum.

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Note: Figure translations are in progress. See original paper for figures.