FAST ELECTRONS AND X-RAY RADIATION IN THE INITIAL STAGE OF DEVELOPMENT OF A PULSED SPARK DISCHARGE IN AIR

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Abstract

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FAST ELECTRONS AND X-RAY RADIATION IN THE INITIAL STAGE OF DEVELOPMENT OF A PULSED SPARK DISCHARGE IN AIR

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To elucidate the mechanism of development of a spark discharge in gases at high pressures, the question of the energy of electrons in avalanches at the initial stage of the discharge is of substantial importance. It is known (1,2) that at voltages close to the static breakdown values, the kinetic energy of electrons in individual avalanches does not exceed several electron-volts. However, when an avalanche grows into a streamer, the field in the vicinity of the avalanche must increase severalfold. In this case, on each path length the electron can acquire more energy than is necessary to compensate losses due to elastic collisions, excitation, and ionization. Under such conditions the electron must be continuously accelerated and, in some cases, acquire an energy comparable in order of magnitude with the applied voltage. An analogous phenomenon should also be observed for electrons of individual avalanches at large pulsed overvoltages.

The lifetime of fast electrons is limited by the time of growth of a streamer moving, under pulsed overvoltages, with a velocity of $(10^8 \div 10^9)$ cm/sec (2,3).

Fig. 1. Experimental arrangement. *1*—photomultiplier; *2*—scintillator; *3*—shock absorber; *4*—absorber; *5, 6*—electrodes

Since the direction of motion of the electrons coincides with the direction of the applied field, their presence in the discharge channel can be detected either by extraction through a window in the anode, or by the radiation arising when they are decelerated in the anode material.

The authors carried out a series of experiments demonstrating the existence of fast electrons in the initial stage of a pulsed spark discharge in air at atmospheric pressure. The experimental arrangement is shown in Fig. 1. A voltage pulse of duration 23 nsec, with a rise time of about 2 nsec, was applied to the discharge gap of length 0.4 mm between electrodes *5* and *6*. The bremsstrahlung, passing through electrode *5* and absorber *4*, fell on organic scintillator *2*, the light flash of which was recorded by an FEU-30 photomultiplier. The photomultiplier, together with the power supply, was placed in a metal housing protecting the circuit from electromagnetic pickup. Control experiments were carried out which confirmed the absence of any influence on the circuit from external fields, illumination, and the shock wave.

At a pulse amplitude of 46 kV and with positive polarity of electrode *5*, the hardness and intensity of the bremsstrahlung were sufficient for transmission, with attenuation by several times, through 2 mm of aluminum (with an aluminum anode 1 mm thick), while at an amplitude of 58 kV it was possible to trans—

0.3 mm of nickel (with a nickel anode). It was not possible to determine the duration of the radiation pulse, since it was shorter than the time resolution of the circuit, equal to approximately 5 nsec. According to estimates, the duration of a single X-ray flash should not exceed 1 nsec. When the polarity of the pulse was changed, the radiation intensity increased sharply, since electrode 6 was made of an alloy containing 95% tungsten.

In some experiments, instead of the absorber shown in Fig. 1, a photographic film was installed, covered with light-tight paper and a lead screen with a star-shaped aperture. Figure 2 shows a radiograph obtained over 100 pulses at a voltage of 52 kV. Electrode 5 was made of sheet beryllium 0.3 mm thick and served as the cathode. The image clearly shows a decrease in the radiation intensity along the radius from the center of the aperture (for Fig. 2, see the insert to p. 66).

An estimate of the radiation intensity, carried out by comparison with a source of monochromatic γ-quanta with an energy of 5.9 keV (the isotope Fe^{55}), showed that, under the experimental conditions described above, in each pulse a radiation energy of about $4 \cdot 10^{-4}$ roentgen is released, which corresponds to approximately $6 \cdot 10^4$ quanta (reduced to a mean energy of 6 keV). For such an energy to be released, it is necessary that at least 200 avalanches of critical dimensions ($5 \cdot 10^8$ electrons in each) be involved in the process of continuous acceleration, at a field strength on the order of 1 kV/mean free path.

The results of the experiments performed show that electrons in the initial stage of a spark discharge can acquire energies comparable in order of magnitude with the applied voltage. Under certain conditions, the energy acquired by electrons as a result of continuous acceleration in avalanches can have a substantial influence on the further course of development of the spark channel.

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