Production of stable plasma vortices in the atmosphere

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By using pulsed discharges in dielectric chambers {A. M. Andrianov *et al.*, Zh. Tekh. Fiz. **39**, 433(1969) [Sov. Phys. Tech. Phys. **14**, 318 (1969)]}, it is possible to inject a dense low-temperature plasma from a vacuum volume directly into the atmosphere. The present communication is devoted to a description of certain effects accompanying this phenomenon.

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A cylinder of organic glass (or of some other dielectric, say ice, polyethylene, etc.) with inside diameter 2.5 cm and length 5 cm was sealed between two disk electrodes and the volume so produced was evacuated to a pressure of approximately 10^{-2} mm Hg. In the center of one of the electrodes there was an opening covered by a metallic or a dielectric film of definite thickness. A voltage 10—12 kV was applied to the electrodes from a capacitor bank with $C = 80\ \mu$F, and an erosion discharge with a current at the maximum up to 250 kA was produced inside the evacuated volume. The pressure then increased abruptly, the diaphragm broke, and the discharge products were injected into the atmosphere. Figure 1 shows motion-picture frames of this process. We note a glowing formation is produced in the atmosphere several milliseconds after the end of the discharge, similar in miniature at least outwardly, to ball lightning, a photograph of which, borrowed from Singer's book [2], is shown in the same figure. The lifetime of the glowing formation, its shape, and its dimensions depend in a definite manner on the energy input, on the material, and on the geometry of the discharge chamber. By increasing the diameter of the ruptured diaphragm it is possible to attain practically complete ejection of the erosion-discharge products from the chamber. Photographs were obtained of a brightly glowing sphere moving at a distance 50 cm from the injector with a velocity of 20 m/sec. The complexity of its local configuration, some singularities revealed in experiments on the interaction with different obstacles, as well as the appreciable duration of the emission, have made it natural to assume that an internal vortical structure is present, apparently initiated on leaving the diaphragm. This assumption was verified by placing an additional cylinder (diameter 5 cm, length 8 cm) above the diaphragm. Figure 2 shows the frames obtained in observation at a small angle to the system axis. On the left is shown the scale of the distance from the injector. The pictures presented, as well as many others obtained by stereoscopic photography in different projections, indicate unequivocally that it is possible to obtain in the atmosphere clear-cut and stable plasma vortex rings moving with velocity 10—20 m/sec. We note that the time of emission of such a ring amounts to at least several dozen milliseconds, whereas the plasma not trapped in the vortex emits its radiation within the first few milliseconds after its escape from the injector tube.

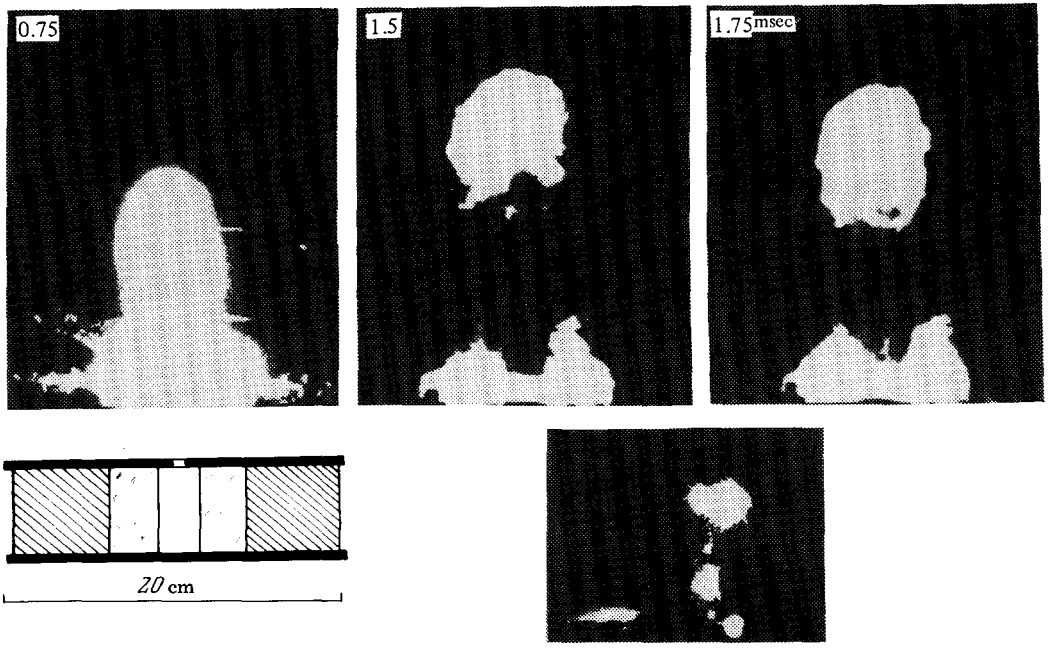

FIG. 1. Ejection of plasma into the atmosphere from an erosion chamber (lower left-diagram of discharge chamber, lower right-photograph of ball lightning taken from [2]).

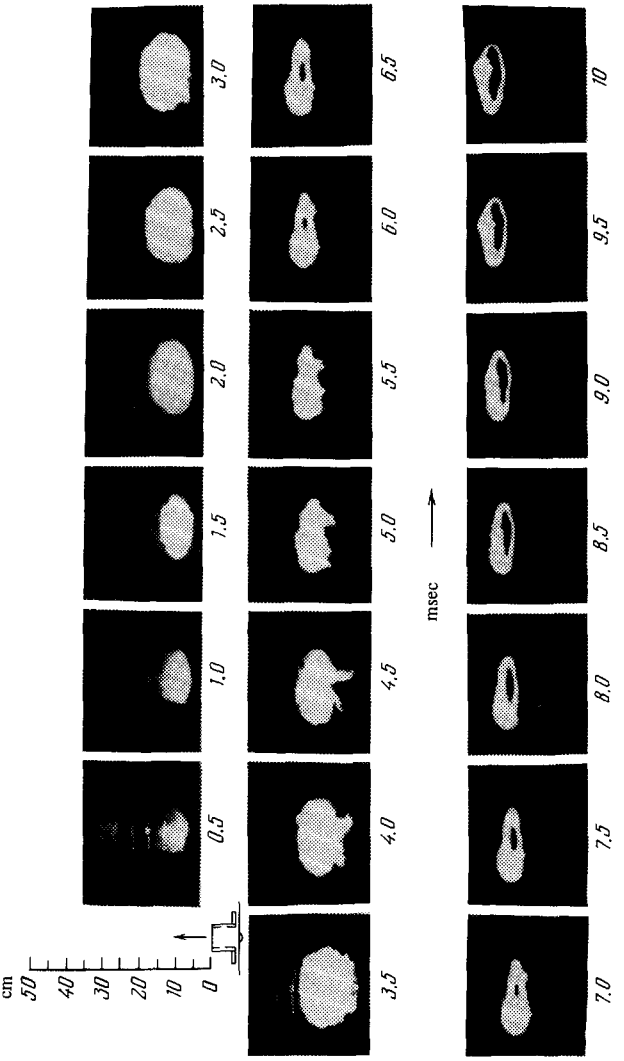

FIG. 2. Formation of plasma vortex in the atmosphere.

Complete de-ionization of a plasma object several centimeters in size should take place within several milliseconds (see e.g., [3]). In our case, as indicated by the photoelectric measurements, the glow of a vortex ring with small diameter 1.5—2 cm continues up to 0.1 sec, and in individual cases can be traced up to 0.3—0.4 sec. It is possible that this prolonged emission and other effects, for example the strong spike-like modulation of the light, can be explained by the Stakhanov "cluster" hypothesis [4], but this hypothesis can be extended only to include the already produced glowing formation and cannot explain in any way the mechanism of its production. On the other hand, if we consider the very process of generation of long-glowing objects, then it appears that the decisive factor must be taken to be their vortical structure, as noted in the Voitsekhovskiĭ paper. [5]

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[5]B. B. Voitsekhovskiĭ and B. V. Voitsekhovskiĭ, Dokl. Akad. Nauk SSSR **218**, 74 (1974) [Sov. Phys. Dokl. **19**, 578 (1975)].