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FEATURES OF FORMATION OF INTENSE ELECTRON BEAMS IN A BOUNDED PLASMA

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Previous efforts [1 - 3] to obtain large-current electron beams from the surface of a plasma yielded currents not exceeding (1 - 2) x 10^3 A. New methods and possibilities of greatly increasing the currents are afforded by forming the beams in a plasma filling beforehand a bounded gap through which a current of 10^4 - 10^5 A is made to flow.

The schematic diagram of the experiments is shown in Fig. 1. The plasma flows from spark source 1 into an accelerating gap 2 (1 - 2 cm). The accelerating field is applied to the plasma-filled gap ($n \sim 10^{12} - 10^{13}$ cm^{-3}) with a delay $\tau \sim 1 - 2$ μsec, and is maintained by a capacitor C_2 = 0.4 μF. A distinguishing feature of the formation of electron beam by first filling the accelerating gap with plasma is that during the initial stage of current development the gap is short-circuited by the plasma and the voltage drop across it is low. When the current in the gap reaches a certain critical value, the ohmic resistance of the gap increases, and this leads to an interruption of the electron current (Fig. 2a) and to a sharp increase of the potential difference on the gap, to a value exceeding the initial voltage of the power supply. During the stage of interruption of the total current, an electron beam is formed in the plasma, and an appreciable fraction of this current (1/2 - 1/3, Fig. 2b) passes through the grid to the anode and is measured with a Faraday cylinder. The critical current increases with increasing plasma concentration in the gap, and reached 2 x 10^4 A in our experiments. The beam current reached in this case 10^4 A, at a pulse duration 3 x 10^{-7} sec. A characteristic feature of the regimes investigated by us, as shown by probe measurement, is the concentration of the potential difference near the cathode. Such a po-

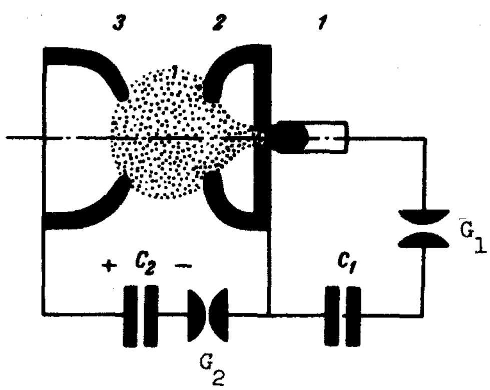

Fig. 1. Schematic diagram of experiment. 1 - spark source, 2 - accelerating gap, 3 - accelerating electrode; G_1, G_2 - discharge gaps.

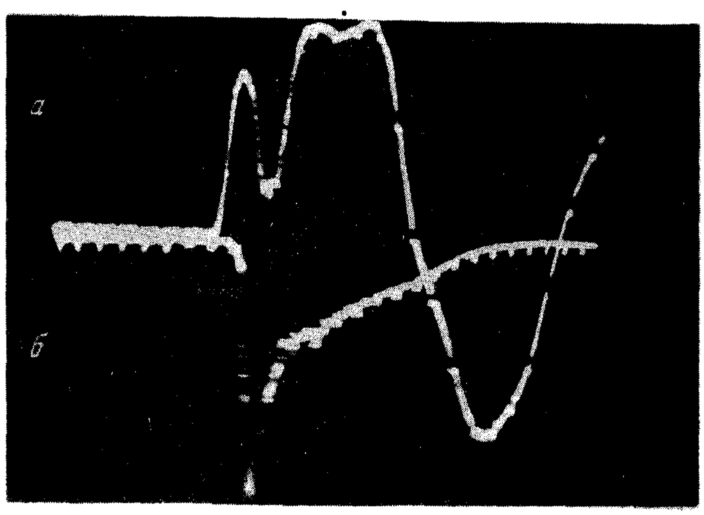

Fig. 2. Current oscillograms: 1 - total current, 2 - current to Faraday cylinder.

tential distribution is established at the instant when the critical current is reached, and is retained during the stage of interruption of the total current. As a result, the plasma in the gap breaks up into cathode and anode sections. The latter has the potential of the anode and acts like a continuation of the anode. The thickness of the space-charge sheath near the cathode can be determined approximately from the "two-thirds" law

$$d = \frac{1{,}5 \cdot 10^{-3} V^{3/4}}{j^{1/2}}$$

at V = 30 kV and $j = 2 \times 10^4$ A/cm^2 we have $d = 3 \times 10^2$ cm and the average field intensity reaches $\geq 10^6$ V/cm. The electron beam accelerated near the cathode passes through the plasma localized in the gap. The beam divergence is eliminated by compensating for the space charge of the beam by the plasma ions, and a strong focusing of the beam is observed. This is confirmed by investigations of the distribution of the x-rays at the anode, performed with an x-ray camera obscura. The beam-current density on the system axis reaches $\geq 2 \times 10^4$ A/cm^2. The point where the beam is focused by its own magnetic field is located at a distance [4, 5]

$$\lambda = \pi b (\gamma / 2\nu)^{1/2},$$

where $\nu = Nr_0$(N - total number of electrons per unit beam length and r_0 - classical radius of the electron), $\gamma = (1 - \beta^2)^{-1/2}$, and $\beta = v_e/C$ (v_e - electron beam, b - initial beam radius). When $N = 10^{13}$, $\gamma \sim 1$, $b \approx 1$ cm, and $\lambda \approx 1.5$ cm. We can expect the electron beam to be initially focused within the length of the accelerating gap (1- 2 cm) so long as the plasma density remains at its upper value. It should be noted that the motion of beams with high current density is possible only if the space charge of the beam is compensated for. In our conditions, the beam is compensated by the plasma ions dragged by the beam in the direction of its motion. When the electron beam passes through the near-anode plasma and the accelerating gap is short (1 - 2 cm), no two-stream instability develops. At a gap length $\sim$ 10 cm, collective interactions lead to large losses of the beam energy in the plasma and to a sharp decrease of the current to the Faraday cylinder.

In conclusion, it can be assumed that when the accelerating voltage is increased to $10^5 - 10^6$ V and the plasma concentration is increased to $10^{14} - 10^{15}$ cm^{-3}, the described method can be used to form beams with currents of $10^5 - 10^6$ A.

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E R R A T U M

In the article by G. I. Iroshnikov et al., Vol. 10, No. 3, p. 97, second line following Eq. (8), reads "...$f_{3\pi\gamma}(\mu^2, \mu^2, \mu^2) \approx 1.1\mu^{-1}\sqrt{\alpha}$," should read: "... $f_{3\pi\gamma}(\mu^2, \mu^2, \mu^2) \approx 1.1\mu^{-3}\sqrt{\alpha}$."