

FORMATION OF THE HIGH-INTENSITY MICROSECOND FLOW OF ELECTRONS IN THE CHANNEL OF HIGH PRESSURE ARC DISCHARGE

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The possibility of microsecond duration powerful electron flows formation in the channel of high current arc discharge at atmosphere pressure has been experimentally demonstrated. The flow of electrons is formed at applying the high voltage pulse to the plasma source after plasma ejection and the pressure decreasing. Because the acceleration by the electric field prevails over the friction force due to collisions the conditions for arising of running electrons are fulfilled.

1. INTRODUCTION

For the solution of some application problems with electron beams using, such as radiation performance, polymerization, modification of surface properties of materials, the necessity of electron beam output into atmosphere is of a great importance. This goal usually achieved by separation of a vacuum chamber of the accelerator and atmosphere by a thin metal foil or application of a complex system of the differential vacuum pumping. More perspective for these purposes can appear the methods of electron flow producing directly in atmospheric conditions.

In [1-4] the formation of fast electrons flow was experimentally investigated and X-ray radiation was registered at the initial stage of the spark discharge in atmospheric air. The pulse duration of the flow was ~ 10 ns at voltages of hundred kV.

In contrast to nanosecond pulse of electron flow obtained early in [1-4] in the resent work the experimental results are represented on the formation of microsecond electron flow in the channel of high-current arc discharge of the plasma accelerator at applying of additional high voltage pulse. Plasma accelerator is working in atmospheric conditions.

2. EXPERIMENTAL SETUP

The scheme of the experiment is presented in Fig. 1. The plasma accelerator (PA) (right part of Fig. 1) is performed from a thick-walled (~ 1sm) dielectric tube of length 40sm with inner diameter 8mm and two electrodes - rod and ring ones. Distance between them is ~10sm. As a power supply the capacity energy store $\tilde{N}2=1.510\text{-}3\text{F}$ was with working voltage 5kV.

The construction and operation of the similar accelerator is explicitly described in [7]. The discharge between electrodes was initiated by high-voltage (~100 kV) pulse with duration at bottom ~ 5 μ s. The

inductance $L=0.3 \mu\text{H}$ prevented with transiting of a trigger pulse in a chain of an accumulator.

After breakdown of the interelectrode gap a power discharge of a capacity accumulator took place. More than 60 % of an accumulated energy transferred in an energy of a plasma bunch.

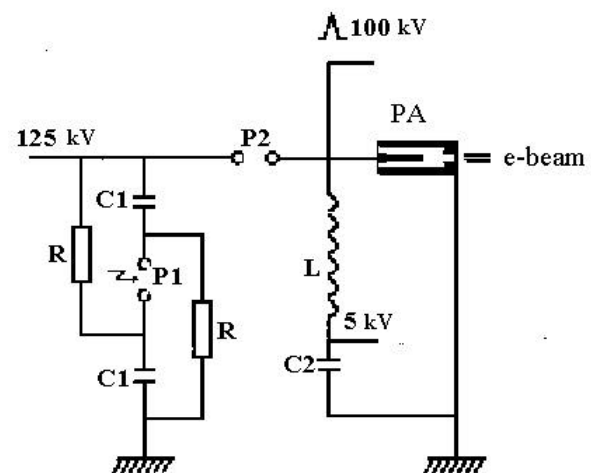


Fig. 1 The scheme of the experiment. PA - plasma accelerator, C2 - capacity bank, 5kV - voltage on bank, L - separating inductance, 100kV - high-voltage pulse, C1, R, P1, P2 - circuit elements of the Marx-generator, 125kV - voltage of the generator.

3. EXPERIMENTAL RESULTS

The specific feature of operation of such accelerator is that after forming of a power electric arc and injection of a dense plasma bunch in a surrounding medium, the pressure in the channel of discharge rises up to 100 μ atm, then the wave of rarefaction follows and the pressure at the end of pulse reduces up to magnitude much below the atmospheric pressure. It can constitute 1-5 \hat{O} irr).

In Fig. 2 the oscillograms of voltage and discharge current are represented. The pulse duration reaches 1.4μs; the maximum of a current constitutes the magnitude 4kA. As follows from the data analysis of oscillograms, after the discharge finishing on the electrodes of condensers of an accumulator the residual voltage up to 2 kV is fixed. In Fig. 3 the specific dependence of resistance of the discharge channel on time obtained at handling and averaging of ten volt-ampere characteristics is represented. It is seen that to the end of pulse the resistance increases sharply. Such situation can arise only at transition of the discharge to the left-hand branch of the Pashen curve. This indicates the fact of considerable lowering of pressure. Otherwise electric arc would not cease.

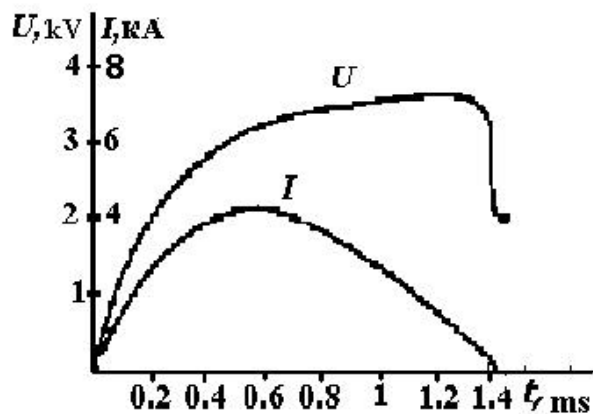


Fig. 2. Oscillograms of a current and voltage of plasma accelerator.

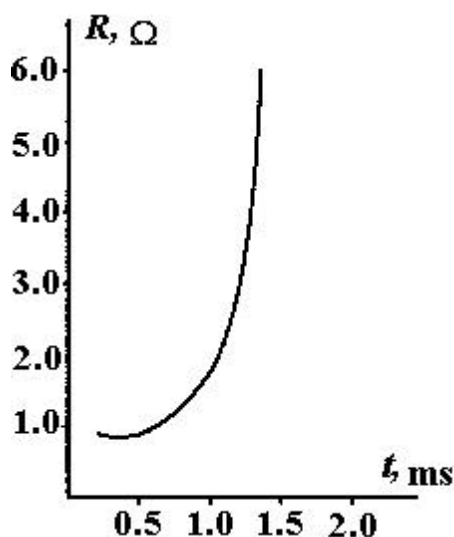


Fig. 3. The dependency of resistance of the discharge channel of the plasma accelerator upon time.

In this instant the negative pulse of high voltage, formed by the two-stage Marx generator (the left part of Fig. 1) was applied to interelectrode gap. Parameters of circuit elements: $\tilde{N}1=0.64\mu\text{F}$, $R=48\hat{\Omega}$, $\Delta 1$ - starting discharger, $P2$ - separating discharger. The charging of generator sections was carried out with the voltage 125kV, and on the load (interelectrode gap PA) the voltage pulse 250kV was formed. Besides the

inductance L prevented transition of short pulse of high voltage in the chain of accumulator C2. The action of high-voltage pulse on a discharge gap of the plasma accelerator being in this instant at lowered pressure, resulted in electrons flow. In oscillograms of Fig. 4. There are represented the current in a chain of discharge of the Marx generator – a, (current was measured by Rogovski belt); voltage applied to accelerating gap – b; ; X-ray radiation registered by a crystal with the photoelectron multiplier – c; and detected HF-signal – d; that is registered by a cut-off horn antenna in the wave band 3-10sm. Sweeping speed of oscillograph – 5μs/div. Sensitivity of current ray – 1kA/div, voltage ray – 125kV/div. From the analysis of represented oscillograms the fact of forming of a microsecond pulse of implies with parameters: current ~1kA, energy ~ 200keV. It should note, that the forming of electrons flow is preceded by a power electric arc in the channel, that heats the emitter (rod electrode) up to melting point. It causes, most probably, termo-electron emission.

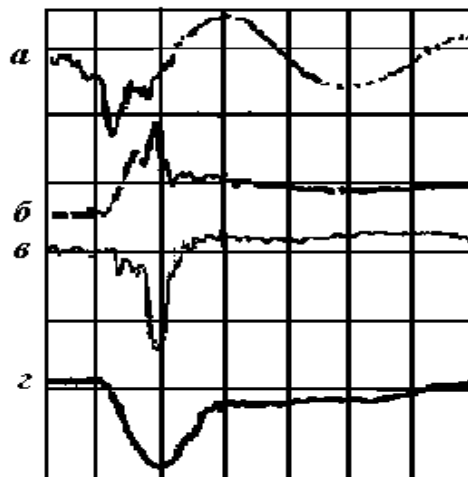


Fig. 4. Experimental results: a - current in a chain of the Marx generator, b - voltage applied to accelerating gap of the plasma accelerator, c - X-ray radiation, d - HF radiation in wave band 3-10sm. Sensitivity of rays of the oscillograph: current – 1kA/div, voltage – 125kV/div, sweeping speed of oscillograph - 5μs/div.

4. DISCUSSION

The formation of the flow is conditioned by the effect of electrons running [5,6]. For the nonrelativistic electron this phenomenon will take place, if the friction (drag) force is less, than electrostatic force caused by an action of an outer accelerating field. In this case the friction force is caused by ionization losses and is described by the known Beta – Blokh formula:

$$F(\epsilon) = -\frac{n_0 e^4 Z}{8\pi \epsilon_0^2 \epsilon} \ln \frac{2\epsilon}{I} \quad (1)$$

where e - electron charge, ϵ - its kinetic energy, n_0 - density of gas molecules, Z - atomic number, I - averaged energy of inelastic losses, ϵ_0 - permittivity of vacuum. The value of a critical field E_k , above of which the running (escaping) electrons appear, is defined from expression:

$$E_{\hat{e}\delta} = \frac{e^3 n_0 Z}{4\pi \epsilon_0^2 2,72 \times I} \quad (2)$$

The relation (2) can be conversed [6] to the formula, more convenient for practical estimations:

$$\frac{E_{\hat{e}\delta}}{P} = 3.88 \times 10^3 \frac{Z}{I} \quad (3)$$

in which value $\frac{E_{\hat{e}\delta}}{P}$ and I are measured in $\frac{V}{cmTorr}$ and eV , accordingly. $I_{air} = 15 - 80 eV$.

The estimation of magnitude of the ration $\frac{E_{\hat{e}\delta}}{P}$ from the formula (3) allows making a conclusion about the possibility of the effect of electrons escaping (running) at experimental conditions.

As the pressure in the discharge channel during the plasma accelerator operation is reducing up to magnitude $\sim 1-5 \text{ Torr}$ and the averaged magnitude of an electric field strength $\sim 20 \text{ kV/cm}$, so in experiment conditions $\frac{E}{P} \sim (0.4-2) \cdot 10^4 \frac{V}{cmTorr}$. The value $\frac{E_{\hat{e}\delta}}{P}$ for air, calculated by the formula (3), is equal $(0.8-3.5) \cdot 10^3 \frac{V}{cmTorr}$, that appears considerably lower than values obtained in the experiments.

4. SUMMARY

Thus, as a result of the performed investigations the possibility of forming of a power flow of electrons of microsecond duration in high-current electric arc not in vacuum conditions is shown.

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