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LOW-PRESSURE PULSED RF DISCHARGE FOR THE FORMATION OF A PLASMA ANODE OF A HIGH-CURRENT ELECTRON GUN

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Main stimulus to use RF discharge for plasma anode formation:

- the possibility to provide an enlarged density on the periphery of plasma anode, that improves the uniformity of a non-relativistic, high-current electron beam formed in the gun;

- plasma anode formation does not depend on the condition of the collector surface that is peculiar to the case of traditionally used high-current reflective discharge operating with the cathode spots.

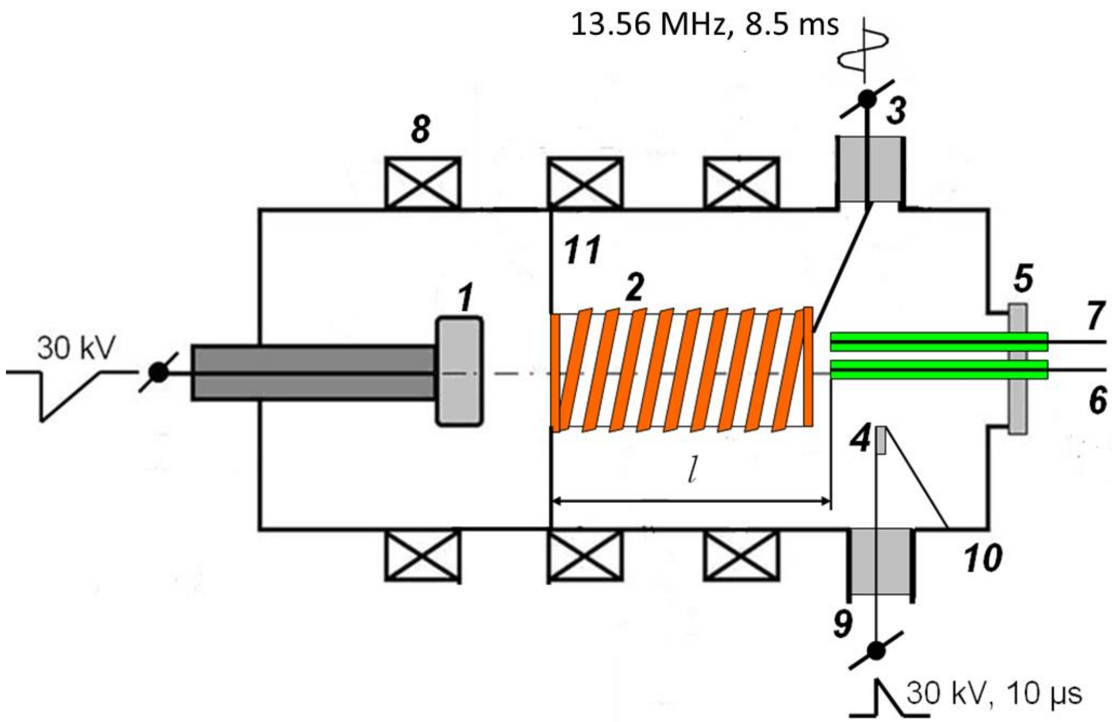


Fig. 1. Experimental arrangement. ***1*** – explosive-emission cathode; ***2*** − inductor (*L* = 170 mm); ***3*** – RF voltage input; ***4*** − auxiliary spark gap; ***5*** − flange; ***6, 7*** − probes; ***8*** − solenoid; ***9*** – spark gap input; ***10*** – electron gun casing; ***11*** – diaphragm.

TYPICAL WAVEFORMS

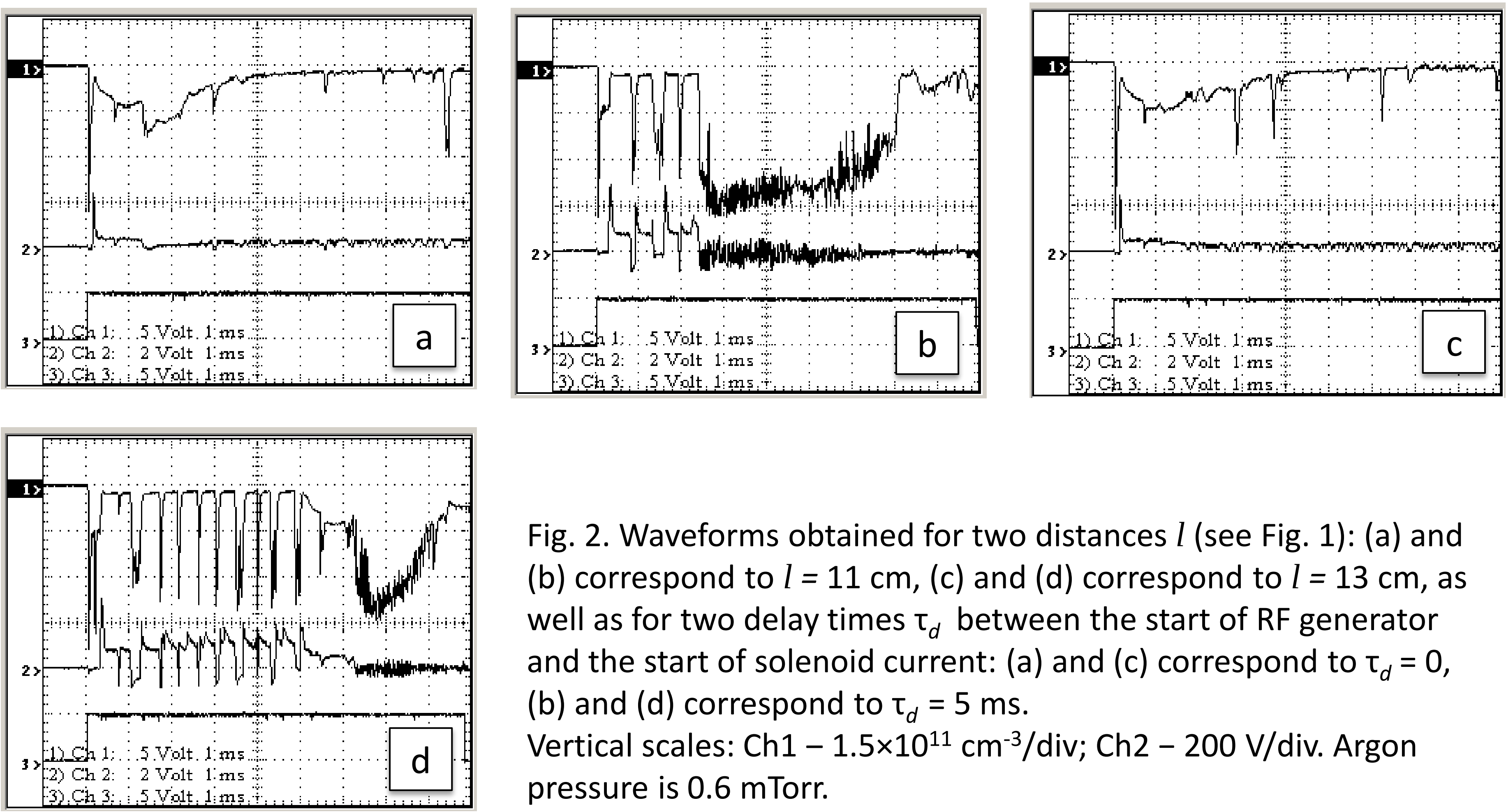


Fig. 2. Waveforms obtained for two distances *l* (see Fig. 1): (a) and (b) correspond to *l* = 11 cm, (c) and (d) correspond to *l* = 13 cm, as well as for two delay times τ_d between the start of RF generator and the start of solenoid current: (a) and (c) correspond to $\tau_d = 0$, (b) and (d) correspond to $\tau_d = 5$ ms.
Vertical scales: Ch1 – 1.5×10^{11} cm^{-3}/div; Ch2 – 200 V/div. Argon pressure is 0.6 mTorr.

PLASMA DENSITY DISTRIBUTIONS

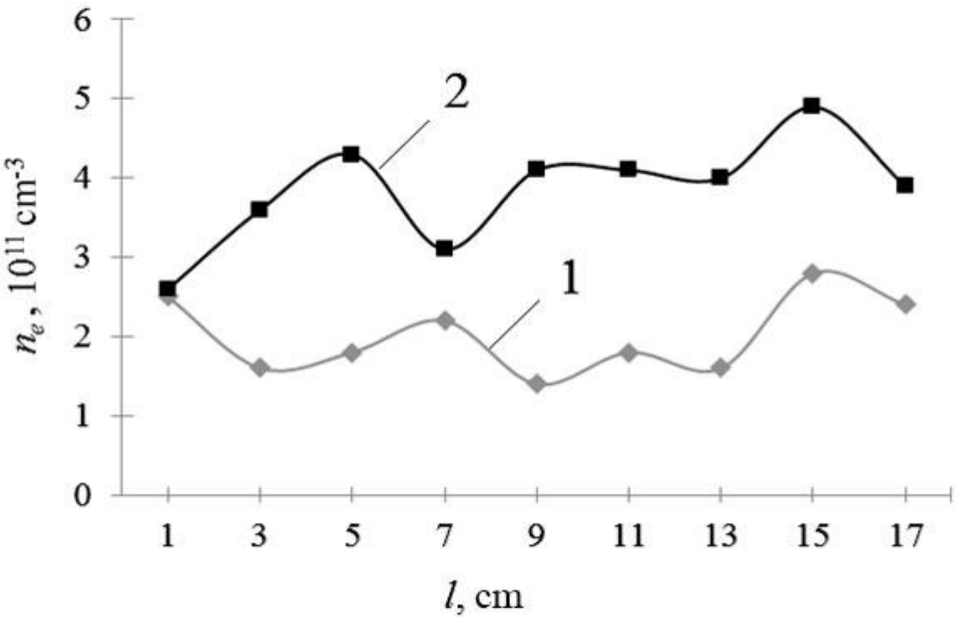


Fig. 3. Plasma density distribution along the inductor axis for two delay times τ_d.
1) τ_d = 0; 2) τ_d = 5 ms. Argon pressure is 2 mTorr.

- At τ_d values of several milliseconds, most of waveforms looks as those given in Fig. 2b,d. The first stage consists of several short (~ 100 μs) sharp spikes and the second stage with more gradual changing of the probe signal.

- At $\tau_d = 0$, the amplitude of the probe current falls down by three times in average; the spikes are also observed but more rare. This indicates to the difficulty of the working gas ionization caused by the action of magnetic field created by solenoid.

- The plasma density value is rather low (not more than 5×10^{11} cm^{-3}, see Fig. 3), and this makes the operation of explosive-emission cathode very unstable as we shall see below.

- Increasing of the argon pressure up to 5 mTorr did not provide proportional increasing of the plasma density which rose essentially slowly.

RF DISCHARGE PLASMA GLOW

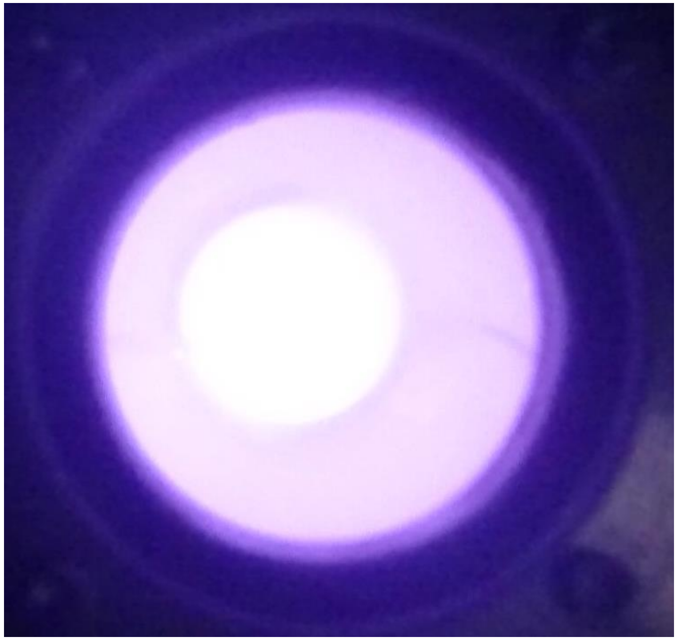
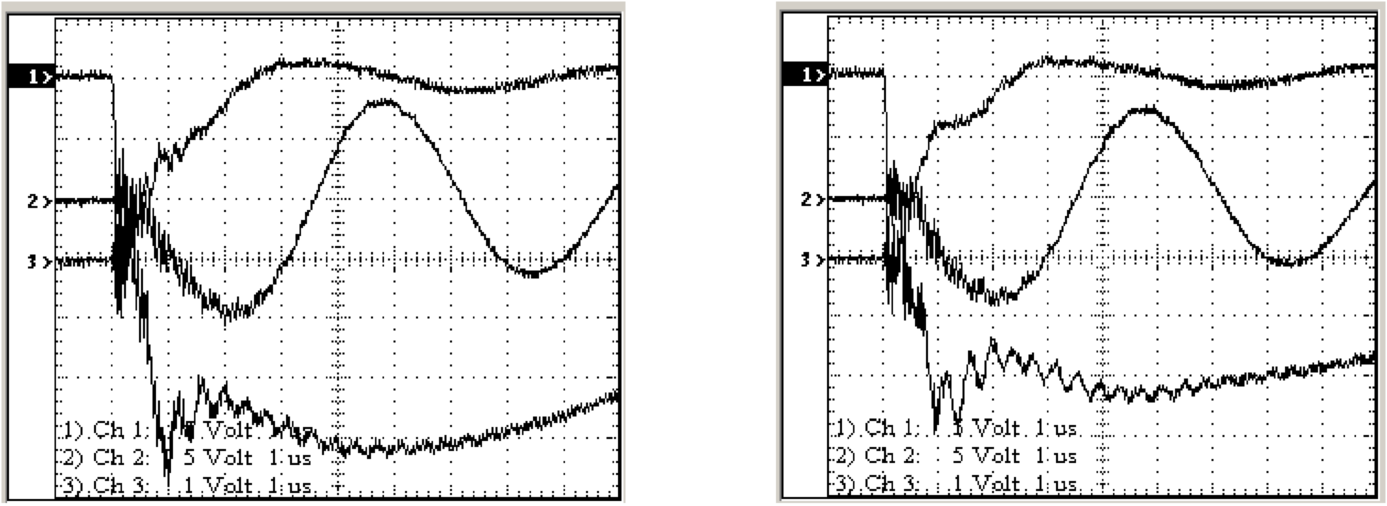


Fig. 4. Photo of the RF discharge plasma glow through the end window. Argon pressure is 0.6 mTorr.

The plasma concentration 5×10^{11} cm^{-3} is insufficient to generate the beam. The delay between the accelerating voltage pulse and the cathode/collector currents is tens of microseconds. And only at the pressure of 5 mTorr this delay decreases to 0.2–0.4 μs.



(a) (b)

Fig. 5. Waveforms of the accelerating voltage (Ch1, 10 kV/div), cathode current (Ch2, 25 kA/div) and beam current onto the collector (Ch3, 1 kA/div) for different delay times: (a) – τ_d = 5 ms, the delay of accelerating voltage pulse relatively to the start of solenoid current is 1 ms; (b) – τ_d = 0, the delay of accelerating voltage pulse relatively to the start of solenoid current is 3 ms. Argon pressure is 5 mTorr. Charge voltage of the high-voltage pulsed generator supplying electron gun is 20 kV.

CONCLUSIONS

1. Pulsed inductive RF discharge was firstly used for creation of a plasma anode of high-current electron gun. For reliable and stable ignition at low pressures (~ 1 mTorr) of the working gas, it is needed to inject free electrons into an inductor, for example, from an auxiliary spark. Plasma anode glow looks diffused and uniform.

2. Plasma density measured in our experiments did not exceed 5×10^{11} cm^{-3}. Such value is insufficient for acceptable operation of an explosive-emission cathode. The beam energy density obtained with the use of such a plasma anode did not exceed 2 J/cm^2.

3. Further increasing of the plasma density and the beam energy density may be provided by the increasing of RF generator power and/or increasing of the energy input into discharge.