STUDYING THE ELECTRON FLOW FORMATION IN MAGNETRON GUNS WITH A SECONDARY EMISSION METALLIC CATHODE

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Presented are the results of studies concerning the multybeams systems and considering the possibility to increase the output current amplitudes by changing the geometrical dimensions of guns.

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INTRODUCTION

The problem of extending the life-time and increasing of the pulse and average power of many RF-sources is closely related to the design of their electron guns. As it is known, the magnetron injecting guns with secondary emission metallic cathodes (SEMI) are specified by the high current emission density and long life-time. The main goal of these investigations is to determine the advantages and limitations of using SEMIGs as the electron source in high-power RF devices and accelerator injector systems. At this stage we have studied some questions concerning the operational beam stability, voltage and current increasing. The experiments have been performed by using the experimental setup to investigate SEMIG linear electron beam parameters from single and multiple beams gun assemblies with the anode voltage up to 100 kV, pulse duration up to 10 μs, repetition rate 50 Hz and 0.1-0.2 T magnetic field strength. Pulse-to-pulse long-term stability of the annular electron beams (internal diameter nearly equal to the cathode diameter, wide of ring 1-2 mm (wavelength of cyclotron oscillations)) with beam density up to 70 A/cm^2 (10^{10}-10^{11} e$^-$/cm^3) has been achieved. It is shown, that the cathode diameter extension provides a proportionate increasing of the beam current, and in the case of multiple beam gun assemblies we have separate identical electron beams with the similar parameters of single-beam gun.

A task of creating the long-lived high-energy electron sources is one of the main problems in the acceleration engineering. As it was shown earlier [1, 2] the so-called secondary-emission magnetron guns (SEMIG) with cold metal cathodes are specified by a high beam density, high lifetime and instantaneous operation readiness. On our opinion the guns of such a type are highly promising for the use in RF-sources and accelerators, in particular, in multybeam and cluster klystrons [3, 4] as well as in high-current injector systems, for example, in the installation such as RK TBA [5], CESTA TEST FACILITY [6] and ion accelerators driving ring electron beams [7].

The present paper continues the experimental study of characteristics of such guns. We studied the current-voltage and spatial characteristics, conditions of beam generation and stability. The amplitude modulation of the emission current in the variable electric fields was investigated. Presented are the results of studies concerning the multybeams systems and considering the possibility to increase the output current amplitudes by changing the geometrical dimensions of guns.

FACILITY DESCRIPTION

Investigations on the beam generation in magnetron guns with secondary-emission cathodes were conducted at the facility the layout of which is represented in Fig. 1. In these experiments the pulse of a negative polarity from modulator 1 forming the voltage pulse (amplitude 4 to 100 kV, duration 4 to 10 μm and repetition rate 50 Hz) is fed to cathode 5 of the gun and its anode 6 is grounded via resistor R_3 and connected to generator 2. The process of secondary-emission electron multiplication took place at the fall of the voltage pulse being formed with modulator 1 or generator 2.

The magnetic field for the beam generation and transport was created with solenoid 4 consisting of 4 sections having 550 mm length and being supplied from independent current sources that allowed one to change the spatial distribution of the magnetic field and its amplitude. The beam transport was performed at a distance 80 to 160 mm from the anode cut to the Faraday cup.

Measurement of the beam current was conducted with applying Faraday cup 7 made as a section of the coaxial line and resistor R4=12 Ohm equal to the wave resistance of the line; the cathode voltage was measured with the use of divider R_1R_2; the beam dimensions - with the use of a dent on the X-ray film and on the molybdenum foil disposed at the coaxial line end. The magnetron gun with a copper cathode and an anode made from the stainless-steel or copper having 120 mm length was placed inside vacuum chamber 3 evacuated to a pressure of $\leq 10^{-6}$ Torr.

EXPERIMENTAL RESULTS AND DISCUSSION

The electric field in the anode-cathode gap, which is required for the beam generation in the magnetron gun, should have two time intervals: the first is the section with the field fall where the secondary-emission multiplication and the formation of an electron cloud around the cathode occur, and the second is the section with a constant field providing the steady-state stage of the secondary-emission process and beam generation [8,9]. The fall sharpness and duration determine the stability of beam generation and temporary instability of beam current pulse front generation. A non-uniformity at the flat - top part of the pulse can lead to the beam current pulse modulation or to the current pulse blowout as well as to generation of several electron clusters in the single voltage pulse [8] and determines also the permissible spread of the electron beam energy.

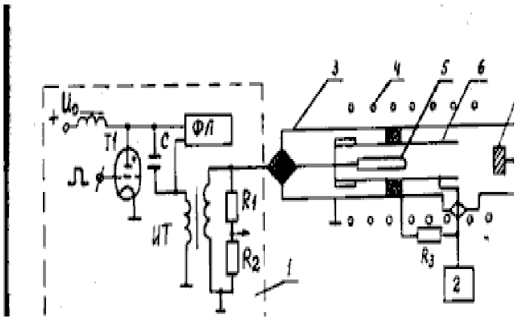


Fig. 1

The given time dependency of the electrical field between the cathode and the anode is gained by forming the voltage pulse of a special form with the burst at the top having a short fall and long flat part at the cathode or with simultaneous feeding of two voltage pulses towards the cathode and anode forming the given electric field.

The first method was based on forming a cathode voltage pulse of a special form with the blowout at the top. In the modulator with a complete discharge of the forming line a voltage pulse with the blowout and flat part can be obtained using a correcting capacity C (Fig. 1) connected in parallel to the forming line [10]. Changing the C value one can regulate the burst amplitude.

A feasibility of forming the burst at the cathode voltage pulse was checked experimentally. The forming line had the wave resistance of 40 Ohm, pulse duration at a half-height of 4.5 µm. The voltage pulse of a modulator being “on no load” at C=0 had the burst of 25% of the voltage pulse amplitude (Fig. 2). When connecting the capacity C =15 nF the burst amplitude was 50% (curve 1) of the voltage pulse amplitude. In one of the operating modes when generating the 9A electron beam the burst amplitude was ~ 60 kV, the amplitude of the flat part during “on no load” operation was 37 kV and “with the beam” ~ 30 kV.

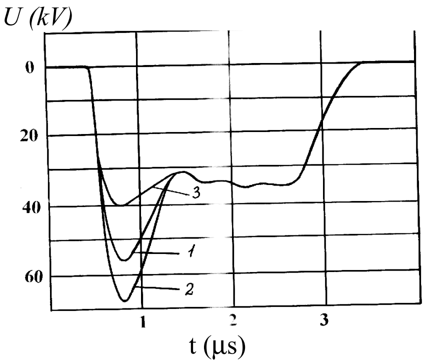


Fig. 2

The second method (Fig. 2) consists in summation (with a total load - cathode, two voltage pulses) of the long pulse with a flat top and the short pulse with a sharp fall, and formation of the voltage pulse having the form close to that of above mentioned one.

Experimental study of this scheme for forming the pulse was conducted at a wave resistance of the forming line ρ=15 Ohm. The burst amplitude was ~ 15 kV, flat-topped pulse amplitude at a beam current of 23 A was ~ 13 kV (Fig. 3). The burst amplitude and the amplitude of a main part of the pulse during beam generation are almost equal. The fall duration in this scheme, like to the first method, equals to hundreds of nanoseconds that is connected with the influence of stray parameters of the modulator output circuit.

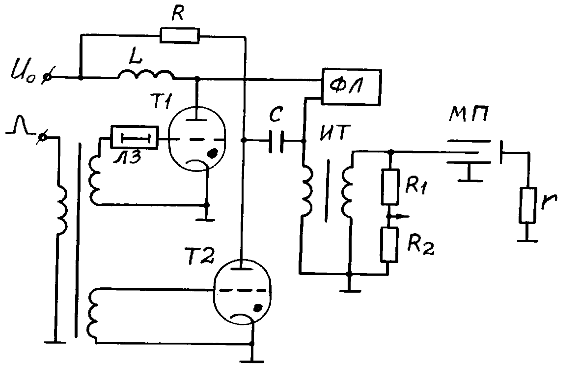


Fig. 3

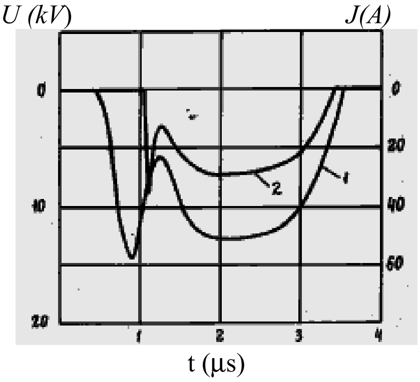
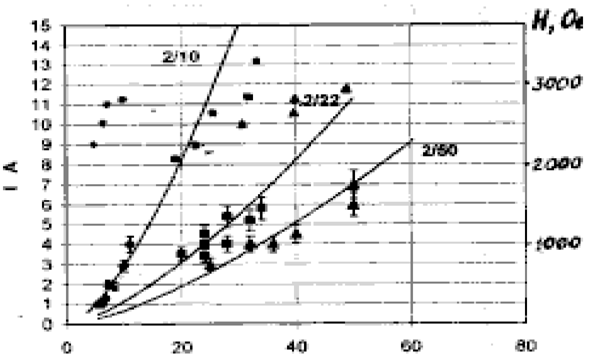


Fig. 4

The third method is the summation in the anode-cathode gap of the electrical fields of two pulses: long flat - topped pulse being fed towards the cathode, and short pulse with a sharp fall being fed towards the gun anode in order to obtain the given time dependence of the summated electrical field [8]. The electrical fields of these pulses are summed in the anode-cathode gap. In this scheme the sharing of pulse feeding circuits permits to use a wide-band transmission line. Duration of the fall pulse at the anode providing a process of secondary-emission multiplication and beam current pulse timing can achieve several nanoseconds (Fig. 4).

Investigations of beam parameters were carried out with the use of all the described above methods of forming a voltage pulse. The experiments have shown that the beam current amplitude at the Faraday cup has a threshold dependence on the fall sharpness and does not depend on the scheme of secondary-emission process excitation. The minimum fall sharpness at which one observes beginning of the process of secondary-emission multiplication and beam generation equals 20 to 30 kV/µs. In Fig. 5 represented is the dependence of the current towards the Faraday cup on the voltage amplitude at the cathode with a diameter of d=2 mm and anode diameters D=10 mm; D=22 mm and D=50 mm. The figure shows that the measurement results are in accordance with the calculation by the "3/2"law. In the process of measuring, in each of points, the magnetic field value was set respectively to the maximum beam current value. In this figure given are the magnetic field values at which the beam generation takes place. In the gun with a cathode diameter of 2 mm and an anode diameter of 50 mm with a voltage amplitude at the cathode of 50 kV a beam current of 7 A was gained. The magnetic field strength was 2550 Oe.



U (kV)
Fig. 5

We have carry out research on generation of electron beams in the magnetron guns of a large aspect ratio with a cathode diameter of 2 mm and an anode diameter of 50 mm and 78 mm depending on the magnetic field value. It is shown that for the voltage amplitude of flatted-top pulse 40 to 50 kV and low magnetic fields (700 to 1200 Oe) one observes the generation of electron beams with a current of 0.5 to 1.5 A (the Hall cutoff field was ~ 600 Oe and ~ 400 Oe, respectively). Here the outside beam diameter was ~ 15 mm. In this case the beam from the magnetron gun with a cathode diameter of 2 mm and an anode diameter of 50 mm at a distance of 130 mm from the anode cut had an outside diameter of 4 mm and inside diameter of 2 mm. The measurement results are given in the table.

d mm	**D mm**	**U kV**	**I A**	**H Oe**
2	50	40…55	0,8	800…1200
2	50	40…55	7	2500
2	78	40…55	1,0	700…1200

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