

STABILITY OF ELECTRON BEAM PARAMETERS IN SOURCES WITH COLD SECONDARY-EMISSION CATHODES

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Abstract

The investigation into the generation of tubular electron beams and their parameters in a system of secondary-emission cathodes was carried out. The parameters of electron beams in a multi-cathode secondary-emission source and a single magnetron gun with the use of a multi-channel measuring system were measured. The stability of the beam current amplitude and a net charge in the beam (pulse to pulse), current distribution on the azimuth were studied. In the 8-cathode system at a cathode voltage of ~34 kV and a magnetic field strength of ~3500 Oe the total current of all beams was ~35 A and its stability was 4±5%. In the single magnetron gun at a cathode voltage of ~30 kV and a magnetic field strength of ~2500 Oe the beam current was ~60 A. And its stability was 2±4%.

1 INTRODUCTION

The electron sources with cold metallic secondary-emission cathodes in crossed fields are of interest as sources of tubular multi-beam electron beams for the

measured the beam parameters in the system with a very non-uniform electric field and in a single magnetron gun. The parameters such as a stability of the electron beam current amplitude and a shape of the electron beam cross-section were studied.

2 EXPERIMENTAL INSTALLATION AND PROCEDURE

The system with a common coaxial anode (1,2) inside which the secondary emission cathodes are arranged is shown in fig.1a. The system comprises 8 copper cathodes (3) of 5 mm diameter. The cathodes are arranged uniformly inside the common coaxial anode on the circle of 44mm diameter. The diameter of the external cylinder of the anode (1) is 68 mm, the diameter of the internal cylinder (2) is 20 mm. The anode cylinders are made from stainless steel and are connected between them with a metallic flange with holes through which the cathodes are put in. The experiments were carried out at the installation [1] the layout of which is presented in Fig.1b.

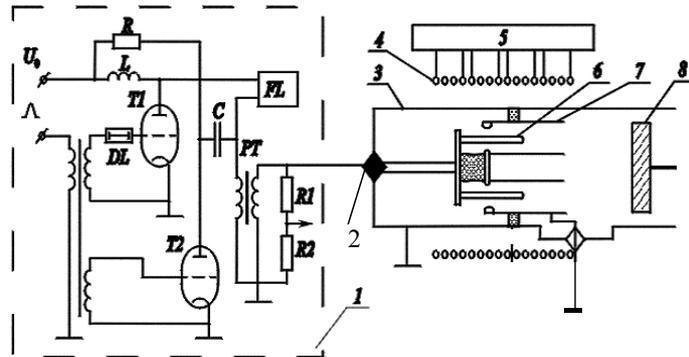
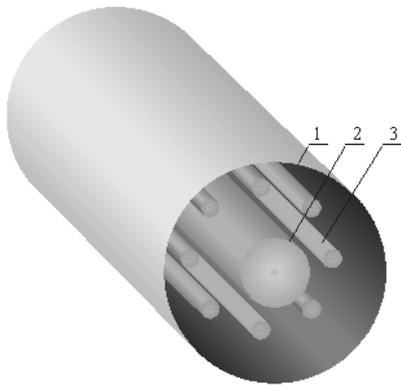


Figure 1 a) Multicathode system. 1,2-anode cylinders; 3-secondary emission cathodes, b) Experimental installation arrangement

microwave high-voltage pulse electronics. Arrangement of cathodes and anodes in the system determines the electric field uniformity and, respectively, the beam generation conditions in it [1]. Till recently, the investigations were carried out with the secondary-emission magnetron sources having a non-uniform electric field distribution on the azimuth [1-3]. In paper [4] studied are the processes of the spatial-periodic beam generation in a multi-cellular system with a non-uniform electric field distribution. Another configuration of a non-uniform system is a multi-cathode system in which the cathodes made in the form of metallic rods are arranged inside the common cylindrical anode. In the present work we have investigated the electron beam generation and

A voltage pulse necessary for the beam generation was shaped in pulse modulator 1 by adding the pulses from two pulse generators in thyratrons T1 and T2 [5]. To cathodes 6 of the system through isolator 2 the voltage pulses were applied with an amplitude overshoot up to 100 kV and a pulse flattop duration of ~ 5μs (of a controllable amplitude) with a repetition rate of 15 Hz. Anode 7 of the system is grounded. The onset of the secondary-emission process was taking place at the peak decay (duration of ~0.3 μs, slope of ~150 kV/μs).

The multi-cathode electron source was placed in vacuum chamber 3 where a discharging of $\sim 10^{-6}$ Torr was maintained. The magnetic field for beam generation and beam transport was created by solenoid 4 supplied from source 5.

To study the parameter of each of beams we used sectionalized cooled Faraday cap 8 (each section of which, of 10mm diameter, recorded the beam from one cathode) disposed at a distance 40 mm from the anode cut. The scattered electrons come onto the block of Faraday cups enveloped by the mask. To investigate the spatial and time uniformity of a beam one of the Faraday cups was covered by the silver shield with a thin radial slit. ($D \sim 0.5$ mm) that allowed observing the beam glow and evaluating visually its transversal dimensions.

The pulses from the Faraday cups, masks, cathode voltages (from the high-voltage divider) arrive into the computer. The measuring system allows one to process (with a discreteness of 100 ns) 32 pulses following one after another by 12 channels: 10 beam channels, the voltage pulse channel and the microwave signal channel. We have measured the current amplitude for each of beams, the mean cathode voltage amplitude, the total beam current and the coefficients of maximum pulse amplitude deviation from the mean value (that is equivalent to the stability of beam currents and cathode voltages). These parameters were measured in the given time point – at the beam current pulse flattop and were averaged for 32 pulses. The measurement error is $1 \pm 2\%$. Besides, the mathematical processing of a pulse sequence (determining their area) was performed to determine the voltage stability and the net charge of beams.

3 EXPERIMENTAL RESULTS AND DISCUSSION

In the system under consideration the generation of 8 electron beams was obtained. At a cathode voltage of 34 kV and a magnetic field strength of ~ 3500 Oe the average value of the current from each of 8 beams positioned on the azimuth changed from 3.15 A to 3.48 A ($\pm 5\%$), and at a voltage of 28 kV it was from 2.5 A to 2.8 A ($\pm 6\%$). This difference is caused by the unequal conditions of beam generation by each cathode that can take place because of the inaccuracy of assembling the system and upsetting the centering of each of cathodes relatively to its Faraday cap.

Fig.2 shows the beam currents (averaged for 32 pulses), recorded by the measuring systems, from 7 cathodes (I1 ... I7) in one voltage pulse U (beam current pulses from the 8th Faraday cup and from the mask are not shown). From the figure one can see that the beam currents from each cathode are insignificantly different by the amplitude, and the pulse shapes are almost coinciding with each other. The electron beam current reaching the mask in this case is ~ 10 A, and the total beam current is ~ 36 A.

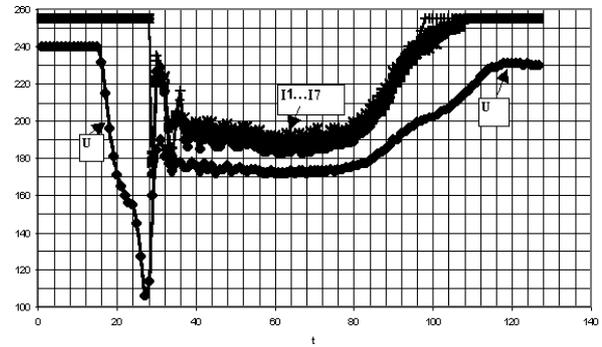


Figure 2. Beam current pulses ((I1 ... I7) and cathode voltage pulse (U)

The processing of the results obtained in several series of measurements showed that at a cathode voltage of 34 kV the current stability was from 1 to 4% for current I1, from 1 to 5% for current I2, and the stability of the total current of all beams was from 2 to 5%. The stability of the voltage amplitude in this case was from 1 to 2%. When processing the results of beam current measurements using another method, i.e. by the total beam current, we have obtained the similar results.

The beam current stability of a short duration, with taking into account three pulses following one after other for current I1, was $1 \pm 3\%$ at the voltage amplitude instability of $\sim 1\%$. This value characterizes the limited possibilities of the multi-cathode secondary-emission system in the given concrete experimental conditions.

The experiments have been performed under conditions of the magnetic field instability (pulse-to-pulse) of $\sim 2\%$. The axis of the system was displaced approximately by 4 mm relatively to the axis of the magnetic field and had the tilt angle $\sim 1^\circ$, the misalignment of the cathode and the anode was $\sim 0.1 \pm 0.2^\circ$.

In the secondary-emission system the beam generation stability is determined by the following factors: number of primary electrons bombarding the cathode surface, their energy accumulation stability, presence of steady processes of the secondary-emission multiplication at the stationary stage of beam generation [1], stability of electric and magnetic fields in time and space, etc. These conditions should be satisfied in each of pulses following one after other. The above given experimental results show that the beam current amplitude stability and, consequently, the total stability of all the factors providing the beam generation can have the value of ~ 1 to 2%.

The electron beam generation with the use of secondary-emission cathodes in non-uniform electric fields has some features. This is concerned, in particular, with a transverse beam current distribution. In paper [4] one considers the shaping of four electron beams in the system of rod cathodes and anodes. Calculations of the electric field non-uniformity on the azimuth showed that near the cathode surface it was $\sim 5\%$. The imprint of each beam on the Faraday cap was in the form of a ring close

to a circle. In our case, because of the cylindrical geometry of the anode, the calculated electric field non-uniformity on the azimuth near each cathode is $\sim 40\%$. Here, the electron drift on the radius, determined by the electric field value, leads to shaping the beam of an elliptic cross-section and to turning the ellipse axis. Then a considerable beam corona is formed that creates conditions for a large current of the mask (~ 10).

Fig.3 presents the photo of electron beam glow at the Faraday cup covered with the silver shield. In the photo there is shown the line of a section of 0.5mm width. The glow was in the form of an ellipse turned at an angle $\sim 45^\circ$ with a wall thickness from 0.5 to 1 mm. When the magnetic field is changing the ellipse axis turns at an angle 90° . The major half-axis of the ellipse was 6.5 ± 7 mm, the minor half-axis was $\sim 5.5 \pm 6$ mm. This result, practically, coincides with the results obtained in [6]. It should be noted that at such a significant value of the field non-uniformity the beam ellipticity is not great and equals to 1.2 ± 1.3 . The processing of measurement results from the Faraday cup sectioned into two isolated parts has shown that the ratio of currents taken from these isolated parts remains constant and has a stability of $5 \pm 15\%$. This indicates on the rather high stability of a beam position at the target.

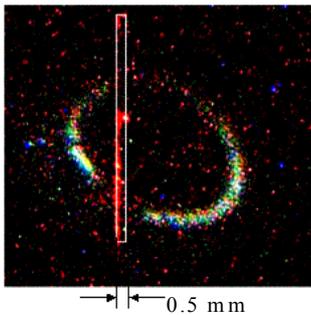


Figure 3. Photography of the beam glow

In the system we observed also the generation of microwave oscillations developed in the course of electron beam shaping. Probably, the microwave oscillations are related with oscillations of the spatial discharge of the electron cloud.

Also, the investigations of the beam current stability in the single magnetron gun with a copper cathode of 40mm diameter and a cylindrical cathode of 50mm diameter

were carried out. At a cathode voltage amplitude of ~ 30 kV and a magnetic field strength of 2500 Oe the beam current was ~ 60 A. The investigation undertaken showed that the current stability of each section in the Faraday cylinder is $2 \pm 4\%$ at a cathode voltage amplitude stability of $1 \pm 2\%$.

4 CONCLUSION

The investigation performed showed, for the first time, a possibility of electron beam generation stabilization in secondary-emission systems. In the multi-cathode electron source the stability of the anode current of each of 8 beams on the azimuth was changing within $\pm 5\%$. It is shown that the beam current stability is $\sim 1 \pm 3\%$ and can reach $\sim 1\%$ under optimum conditions. In the single magnetron gun the beam current stability is $2 \pm 4\%$. Such sources of tubular electron beams can be used in the accelerator technology and in powerful microwave devices.

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