ELECTRON BEAM PRODUCTION IN MULTICATHODE SECONDARY-EMISSION SYSTEMS*

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Abstract

The paper reports the results of investigations on the electron beam production by a system comprising eight secondary-emission cathodes periodically arranged on the azimuth inside the coaxial cylindrical cathode in crossed elecric and magnetic fields. In the system with a nonhomogeneous -on the azimuth – electric field the secondary-emission electron multiplication is realized and the beam production is fulfilled. At the cathode voltage of ~37 kV and magnetic field strength ~3600 Oe, the total current of all the beams is ~35 A and beam current generation stability is ~5%.

1 INTRODUCTION

In the last few years the investigation of electron sources with cold cathodes working under secondary-emission conditions in crossed electric and magnetic fields aroused considerable interest [1 – 6]. The principle of beam production in secondary-emission systems with crossed fields is well-known.

For electron flow generation due to the secondary-emission multiplication it is necessary to create required crossed electric and magnetic fields near the cathode. In virtue of limiting conditions near the cathode surface the electrical field always is perpendicular to the metal surface. Consequently, in all systems with cylindrical and secondary-emission cathodes there are conditions under which the electron beam production due to the secondary-emission multiplication is possible. This can occur also in systems without asimuthal symmetry throughout the region of the interelectrode gap.

Description and investigation of a similar system comprising the rod anodes is given in [7]. In such a system the secondary-emission electron multiplication is realized and the beam production is fulfilled.

Of some interest is the investigation of a nonhomogeneous system similar to the linear system with rod anodes and cathodes made in the cylindrical geometry. The paper presents the results of studying the electron beam production in the multicathode secondary-emission system with a coaxial anode in crossed electric and magnetic field.

2 EXPERIMENTAL INSTALLATION AND PROCEDURE

The experiments have been carried out at the installation the schematic diagram of which is presented in fig.1. The voltage pulse of a special shape, having an amplitude up to 100 kV, duration of the flat pulse part up to 5 μs and pulse-repetition frequency from 12 to 15 Hz, was produced by a modulator 1 and applied to cathodes 6 and anodes 7 which are grounded via a resistor R3. The voltage pulse top required for the beam production was formed on the cathodes of the system by adding together the short pulse from the independent generator using a tiratron T2 and the voltage pulse of a modulator with a flat top using a tiratron T2 [8]. The time of pulse drop was ~0.3 μs and the steepness slope was ~150 kV/μs. A 9-cell pulse forming network (PFN) with a wave impedance of 12 Ω and pulse FWHM width ~7 μs was used.

The multicathode system was placed in a vacuum chamber 3 where a pressure of ~10^{-6} torr was maintained. A magnetic field for beam production and transport was created by a solenoid 4 (composed of 4 sections), which was supplied from a direct – current source 5. The strength and longitudinal distribution of the magnetic field in the vacuum chamber can be controlled by changing the current value in the solenoid sections. The nonhomogeneity of the longitudinal magnetic field in the system and in the channel of the transport to the Faraday cup is ± 8%.

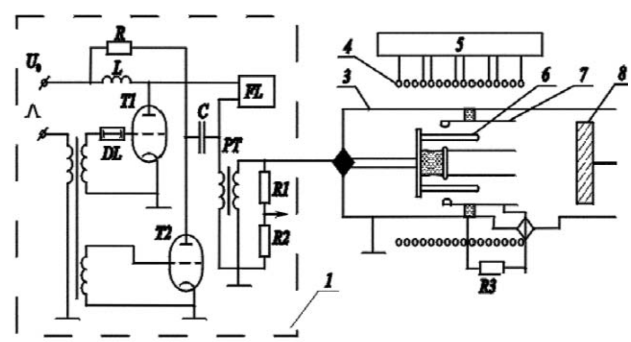

Figure 1: Schematic diagram of the experimental installation

In the course of investigations we have carried out measurements of the cathode voltage, the electron beam current on the Faraday cup 8 and the anode current. Measurement of the voltage pulse parameters was performed using the resistive divider R1 – R2, and the anode current was measured using the resistor R3. The Faraday cup 8 is a segment of the coaxial line with a wave resistance of ~12 Ω, line length of ~ 400 mm, cylinder diameter of 120 mm. The end part of the Faraday cup, onto which the beam falls, is fabricated of stainless steel and has a water-cooling system. The time of beam

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setting up in the measuring circuit is between 1 and 1.5 ns. To study in details the parameters of every of beams we used a multichannel Faraday cup with a connected automatic 12-channel measuring system. To estimate the stability of the shape and amplitude of voltage pulses on the cathode and the beam current on the Faraday cup we used both the oscillographic measurements and the 12-channel measuring system. The beam dimensions were measured using the indentation on the aluminium and molybdenum foil.

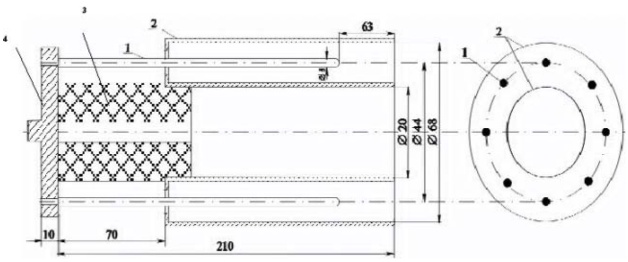


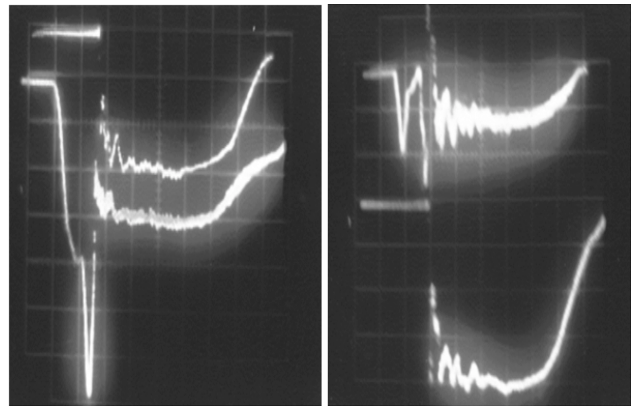
Figure 2: Multicathode system. 1 - secondary-emission cathodes, 2 - anode, 3 - insulator, 4 - metallic disk.

The system under investigation with a cylindrical anode in which the secondary-emission cathodes are placed is shown in fig.2. As is seen, the system comprises 8 copper secondary-emission cathodes 1 (5 mm in diameter), which are fixed on a metallic disk 4. To this disk a coaxial diode 2 is attached via an insulator 3. The diameter of the cylinder of the outside diameter is 68 mm, and that of the inside anode is 20 mm. The anode cylinders are fabricated from the stainless steel and are connected with each other via the metallic flange with orifices into which the cathodes are introduced.

3 EXPERIMENTAL RESULTS AND DISCUSSION

The experiments resulted in realization of the secondary-emission electron multiplication and electron beam production. The total beam at the gun exit included 8 electron beams. At the voltage amplitude ~37 kV and magnetic field strength ~ 3600 Oe the total current of all beams was ~35 A, anode current reached values from 1.5 to 2 A. Experimentally the stable beam generation was obtained for the drop slope ~150 kV/μs. In fig. 3a given are the typical oscillograms of the voltage pulses on the cathode and of the total beam current on the Faraday cup. It is seen that the beam production begins at the drop of the pulse voltage overshoot.The measurements of the time of beam current pulse rise showed that it is between 10 and 12 ns. In fig. 3b given are the oscillograms of the pulse of the total beam current on the Faraday cup and that of the anode current.

It is seen from fig. 3b that the anode current repeats the shape of the beam current and equals to ~ 3 to 5 % of the beam current. The oscillogram of the anode current in the initial part shows a signal related to the overshoot differentiation for the voltage pulse. In the process of measurements the magnetic field being corresponding to the maximum amplitude of the total beam current.



a b

Figure 3: Typical oscillograms of pulses:a) the voltage pulse on the cathode (below) and the beam current pulse on the Faraday cup (above). Vertical scale :8 kV/div and 8 A/div, horizontal scale is 1 μs/div.b) the beam current pulse on the Faraday cup (below) and the anode current of the gun (above). Vertical scale: 8 A/div for the beam current, 1 A/div for the anode current, horizontal scale: 1 μs/div. Magnetic field strength ~3100 Oe.

When carrying out the experiments it was established that in the system the construction in the place of the cathode input into the anode has a significant influence on the stability of the total current generation and its amplitude value. For this purpose we studied the beam production in two variants of gun construction. In the first one the flange connecting anode cylinders is located in the place of the beam output, and the cathode input into the anod is performed through the gap between the inside and outside cylinders of the anode. The experiments demonstrated that there was a stable beam current generation in the first construction, and in the second variant the stable generation was sustained but the beam current was less than in the first variant. In the second construction where the anode had a conical part in the place of the cathode input (in order to increase the electric strength) the beam current had two parts: stable part of generation with a flat top duration from 0.5 to 1.5 μs in the initial part of the pulse, and the next (instable) part of a spiking character with the amplitude of peaks from 5 to 10 A. The magnetic field increasing leaded to increasing the flat top duration (up to 1.5 μs) but had no effect on the character of generation of the next beam part.

The above-mentioned effects are caused by that in the place of the cathode input, when changing the construction, the conditions for development of secondary-emission processes at the initial stage of beam formation are violated. In the case of changing the value and distribution of the edge electric field in the place of the cathode input into the anode both the primary electron quantity and conditions of energy gain by these electrons can be changed. At a high electric field values the electron quantity is large and the electron energy gain takes a shorter time and reaches higher values. At a lower electric field both the primary electron quantity and their energy value and beam production become instable. On the other side, the multicathode system is a system with a nonhomogeneous filed distribution. In this case, according to calculations, the electron movement is changing considerably until to the absence of the self-sustaining process of secondary-emission multiplication.hen, the construction with a cylindrical part of the cathode input into the anode is as a stabilizing area determining the secondary-emission development. Thus, there is the possibility to influence upon the secondary-emission process starting by creating an area of the system with a very nonhomogeneous electric field.

We have performed the measurements of transverse dimensions and electron beam positions on the targets at different distances from the anode (fig. 4): at the anode section (on the left) and on the right at a distance of 72 mm from the anode section (upper half–plane), 70 mm (left lower quarter), 68 mm (right lower quarter).

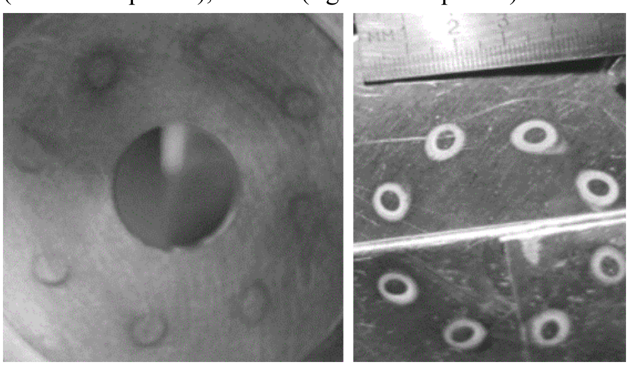


Figure 4: The indentations of beams. On the left – at the anode section, on the right – at a distance 68 – 72 mm from the anode section

The measurements have shown that at the anode output this system generates 8 electron beams in the form of ellipses with a major axis from 6.5 to 7 mm and a minor axis from 5.5 to 6 mm disposed in places corresponding to cathode positions. The thickness of a beam indentation is ~ 1 mm. The axes of ellipses are inclined at an angle of 45° to the circle where the cathode are located (fig. 2). As the magnetic field direction is changing, the inclination of the ellipse axes changes by 90°. The ellipse sizes do not change when measurements are performed at the anode block exit and at the distance 72 mm from the anode block section.

The physical representation of making the indentations of such a sort consists in the following. The electric field distribution in the cross-section of the system is nonuniform, the calculation show that the unhomogeneity of the radial electric field near the cathode surface on the azimuth is ~20%, and the higher field value corresponds to the cathode points located more nearly to the anode. This governs the radial electron drift that results in changing the shape of the beam cross-section: the circle is transformed into the ellipse turned relatively to the beam axis at some angle.

We have carried out the measurements of voltage pulses on the cathode and of the beam current on the Faraday cup with the help of the automatic 12-channel measuring system. Experimental points were obtained by the selection from the running oscillograms with a selection period of 100 ns. This made it possible to estimate the beam generation stability in 32 pulses going one after another, i.e. the pulse-to-pulse ampitude stability. The processing has showed that at the voltage 34 kV the stability of beams was 3…5 %.

4 CONCLUSIONS

So, in electron guns with crossed field, based on multicathode systems with nonhomogeneous electric field distribution, the selfsustaining process of electron beam production due to the secondary electron emission is realized. The electric field distribution in the place of rod input into the anode system exerts a considerable influence on characteristics of beams obtained at the gun output. The electron flows formed at the gun exit are N (N is the cathode number, in our case N = 8) of distinct beams. At the anode block exit observed is the elliptic beam shape which is almost unchangeable in the transport region.

5 REFERENCES

[1] Yu.Ya. Volkolupov, A.N. Dovbnya, V.V. Zakutin et al. *Zhurn.Tekhn.Fiz.*, 2001, v.71, No 2,p. 98-104 (in Russian).

[2] Yu.M. Saveliev, W. Sibbett, D.M. Parkes *Physics of plasmas*, 1997, vol. 4, No 7, P. 2319-2321.

[3]Yu.Ya. Volkolupov, A.N. Dovbnya, V.V. Zakutin . et al. *Zhurn.Tekhn.Fiz.*, 2001, v.71, No 3, p. 78-80 (in Russian).

[4] A.V. Agafonov, V.M. Fedorov, V.P. Tarakanov, *Proc. of 1997 particle Accelerator Conf.*, Vancouver, Canada, 1997, v.2, 1299-1301.

[5] A.V. Agafonov, V.M. Fedorov, V.P. Tarakanov, *Problems of Atomic Science and Technology*, 1999, №4(35), p.11-15.

[6] Yu.Ya. Volkolupov, A.N. Dovbnya, V.V. Zakutin et al. *Zhurn.Tekhn.Fiz.*, 2001, v.71, No 9, p. 134-136 (in Russian)

[7] M.I. Ayzatsky, Yu.Ya. Volkolupov, A.N. Dovbnya et al. *Pis'ma v ZTF, 2001*, v.27, N.23, p.25-30 (in Russian).

[8] A.N. Dovbnya, N.G. Reshetnyak,. V.P. Romasko et al. *Proc. of the 2001 PAC*, Chicago, 2001, p. 3759 – 3761.