# OBTAINING THE LINEAR ELECTRON BEAMS BY USING THE MAGNETRON INJECTION GUNS WITH COLD SECONDARY EMISSION METALLIC CATHODES (EXPERIMENT)

Yu.D. Tur, A.N. Dovbnya, V.V. Mitrochenko, N.G. Reshetnyak, V.P. Romas'ko, V.V. Zakutin
NSC KIPT, 1, Academicheskaya Str., Kharkov, 310108 Ukraine

*Abstract*

The problem of extending the life-time, of increasing 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 (SEMIG) 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$^2$ have 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.

## 1 INTRODUCTION

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] and CESTA TEST FACILITY [6].

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.

## 2 DESCRIPTION OF FACILITIES

Constructionaly SEMIG represents a coaxial structure with a copper inner rod being the cathode and a more extended external cylinder placing the role of the anode placed in the solenoid providing the longitudinal magnetic field. Experimental studies have been carried on the test setup comprising:

i) the high-voltage pulse modulator of a linear type capable to change the pulse shape (duration 2-10 μs, repetition rate 10-50 Hz, pulse voltage 20-100 kV);

ii) the focusing solenoid providing the magnetic field strength up to 0.25 T with a inhomogeneity in the longitudinal direction no more than 8%;

iii) the vacuum system which gives a vacuum not worse than $10^{-7}$ Torr;

iv) the indication system i.e. the pick-up of pulse current and voltage of modulator, the Faraday cup with the calorimetric measurer of the beam power located at a distance of 70 mm from the anode section; photometry system for control of the transversal characteristics of the linear electron flow.

We have carried out the study of beam characteristics for separate SEMIG's with cathode diameters in the range from 5 to 40 mm, anode diameters from 14 to 80 mm, electrode length from 40 to 100 mm. The measurement were performed for parameters of the multybeam system consisting of six SEMIG disposed is a circle of a radius 60 mm, every of them have had a cathode diameter 5 mm, an anode diameter 26 mm.

## 3 EXPERIMENTAL RESULTS

The characteristic oscillograms of the voltage pulse on the cathode and beam current on the Faraday cup are given in Fig. 1. As in the case when the outer generator is used, the beginning of the secondary-emission process, and respectively, of SEMIG operation as a source of the linear electron flow, coincides with the fall time of the burst on the high-voltage pulse. The minimum rate for voltage decrease of the plan pulse part up to 100 kV is 20 kV/μs. The increase of a steepness up to 50 kV/μs does not change the amplitudes of the resulting current, and the change of a burst time in a wide range ( from 0.1

 

to 10 μs) has no effect on the beam characteristics. A comparison of the total current in the system with the current amplitude on the Faraday cup shows that in all the cases these values are dose.

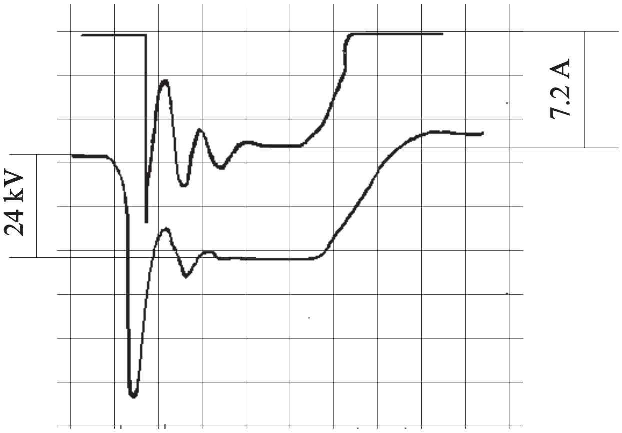


Fig. 1 - The characteristic oscillograms of the voltage pulse on the cathode and beam current on the Faraday cup

In Fig.2 presented is also the typical characteristics of the beam current as a function of the magnetic field amplitude for a constant anode voltage.

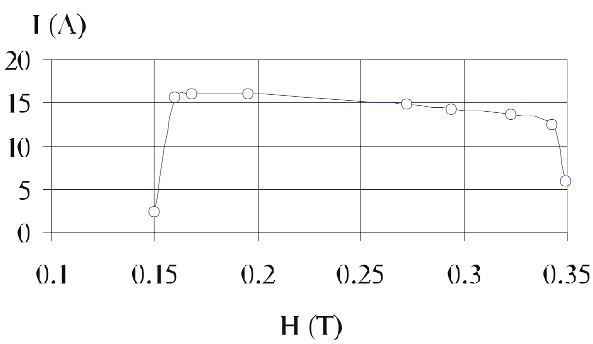


Fig. 2 - Beam current vs. magnetic field

A clearly defined existence of the beam generation stable one can be explained using the model proposed in [7]. If the magnetic field strengths are less than the critical one, the Larmour radius is so large that the quantity of primary particle collisions with the surface can not to furnish a sufficient quantity of secondary electrons for balance maintenance. On the other hand already at high magnetic field the Larmour radius as so small that the energy gained by the electron when colliding with the surface is loss than that of the threshold one for the secondary-emission process be existent. The constant value of the beam current amplitude is determined by the limiting regime by the space charge. The current voltage characteristic of SEMIG's conforms so the low "3/2" (see Fig.3)

The investigation of the gun operation stability dependency on the interpulse stability of the anode voltage has shown that in the constant magnetic field the beam formation retains in the range of amplitude application ±5% of the nominal value.

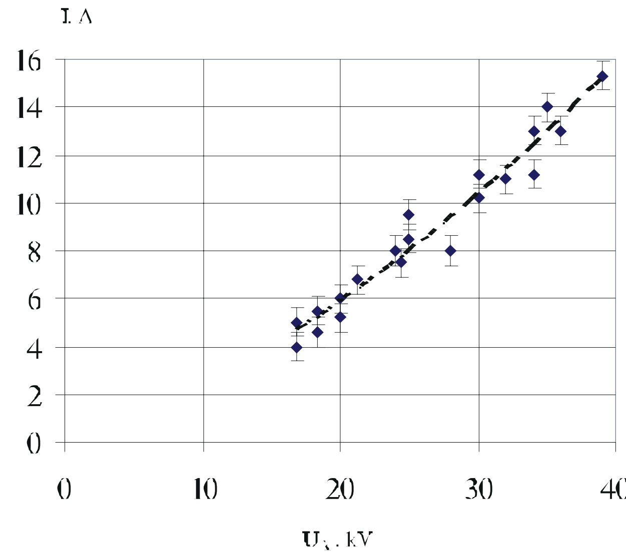


Fig. 3 - The beam current vs. anode voltage

The intrapulse voltage instability can also lead to the break-down of secondary-emission processes (see the oscillogram in Fig. 4) due to the incident electron energy decrease below the critical value of moment of the field strength increase in time.

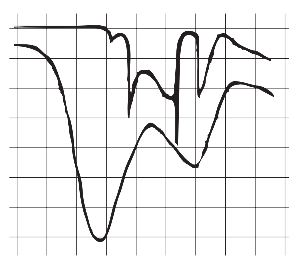

Fig. 4 - The beam current (an upper curve) and the cathode voltage (a lower curve), horizontal scale - 0.5 μs/div

The use of this effect in our experiments allowed us to attain the full amplitude modulation of the emission current at frequencies up to 1 MHz (see Fig. 5).

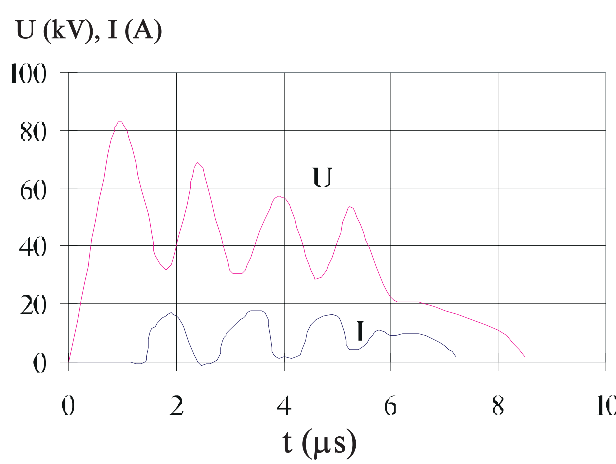


Fig. 5 - The anode voltage (U) and cathode current (I)

Also studied were the characteristics of electron flows from SEMIG's with different electrode diameters. In particular, Fig. 6 represents the beam current change as a function of the cathode diameter increase.

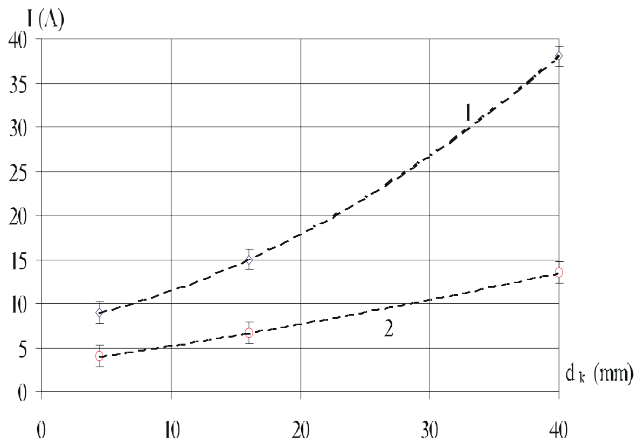


Fig. 6 - The beam current vs. the cathode diameter

The measurements were performed at voltages 24 kV for the interelectrode space in coaxial guns 5 and 20 mm (the curves 1 and 2, respectively). The analysis of these characteristics enables one to confirm that when the values of longitudinal and transverse components of electric field do not change the output current increases proportionally to the area of the cathode emitting surface.

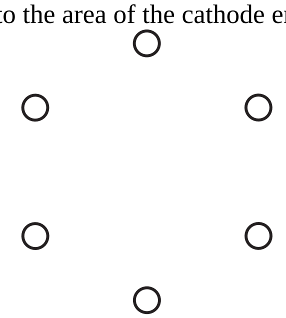

Fig. 7 - The photograph of the transversal profiles of beams

The investigations of the ensemble consisting of a number of SEMIG's located in the field of a common solenoid and energized from the one and the same high-voltage source have shown that in this case we possess a complex of independent flows with a similar parameters.

Fig 7 illustrates the photograph of the transversal profiles of identical beams with the current 15 A each and the energy 40 keV obtained in the ensemble of 6 SEMIG's located in the circle of the diameter 60 mm (cathode diameter 5 mm, anode diameter 26 mm). The recalculation shows that the beam density in such annular beams is equal to 70 A/cm$^2$.

## CONCLUSIONS

The experimental research evidences that SEMIG's offer a means of obtaining the stable linear electron beams of a high intensity and can be used as electron sources for accelerators and RF-facilities. It is clear that the carrying out of further researches is necessary for a successive study of gun characteristics as well as peculiarities of such electron beams RF modulation. Namely these problems lay in the base of our program of researches.

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