FORMING OF HIGH CURRENT DENSITY SHEET ELECTRON BEAMS FOR A SUB-THZ TWT VACUUM AMPLIFIERS

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Abstract: *In this paper we present the computer analysis of magnetic focusing sheet electron beam with low perveance in the electron-optical systems with an electron gun based on thermionic cathode with a current density of 100 A/cm^2 at the distance of tunnel 25 mm.The results of experimental study in the diode mode of impregnated thermionic cathode with linear dimensions 0,1 × 0,7 mm have shown the possibility of using this cathode in sub-THz vacuum amplifier.*

Keywords: impregnated thermionic cathode, perveance; sheet beam; electron gun; terahertz; vacuum amplifier

Introduction

One of the problems that arise in development of sub-THz TWT vacuum amplifiers is to achieve a low value of current deposition in beam tunnel. The planar construction of slow-wave structures [1, 2] involves the use of sheet electron beams, having high level of path of current flow at relatively high output power in a wide frequency range.

High values of current density (up to 1000 A/cm^2) and small sizes of beam tunnel are typical for this frequency range and cause the necessity of application of electronic focusing systems with strong magnetic field. The electron-optical systems (EOS) with electron beam compression and, accordingly, magnetically shielded guns allow to obtain quite high values of current density in the electron beam at lower current load on the cathode and with a lower value of calculated magnetic field. However, the effect of thermal velocity, space charge and aberrations, caused by inaccuracy of production of electrodes, in this case is more significant than that in the case of linear electron optics. Accordingly, the design consisting of linear electron optics and electron gun, immersed inside magnetic field seems as most suitable construction.

Experimental results

In this study the impregnated thermionic cathode with work temperature of 1200 °C has been used (fig. 1). The fabrication of the cathode and anti-emission grid was carried out by precision electric discharge machining. To decrease the work function the thin film of Os has been deposited on the working area of the cathode at the end of fabrication. The experimental investigation of voltage-current characteristic of created cathode has been performed in pulse current mode, using diode structure. The emission current density of more than 85 A/cm^2 has been achieved. It is also assumed for long-term operation of the device to use thermionic cathodes based on alloy Ir-Ce.

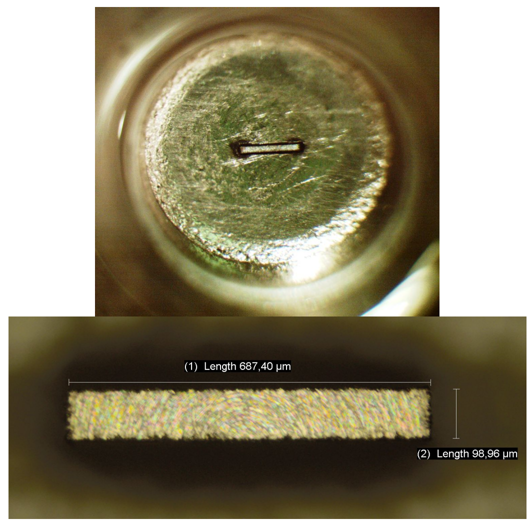

Figure 1. Optical image of fabricated impregnated thermionic cathode (0,1×0,7 mm)

The 3D-analysis of structure of electron beams, formed by EOS with cathode in a uniform magnetic field, has been carried out using Lorentz-3EM software [3]. It should be noted that this CAE-program enables to perform the distributed calculations of fields and movements of electrons in them, effectively using the computational resource during relaxation calculation of space charge. The results of our test calculations of trajectories correspond to the results, presented in [4].

It's known, the formation of extended electron beam having a rectangular cross-section is accompanied by the deformation its shape in the magnetic and electric field. In this case the modeling of sheet electron beam with low perveance, formed by the electron gun, has shown the possibility to obtain the beam without significant deformation of its shape in cross-section. The positions of electrodes in the electron gun (fig. 2) have been determined analytically in accordance with data, presented in [5]. The result of modeling of EOS with sheet electron beam (with current of 70 mA and anode voltage of 20 kV) is shown in fig. 2. Working area of cathode (S_c) is 0,07 mm^2, distance between surfaces of cathode and anode ($d_{c\text{-}a}$) is 2,5 mm and lateral dimensions of beam tunnel are 0,2× 0,85 mm.

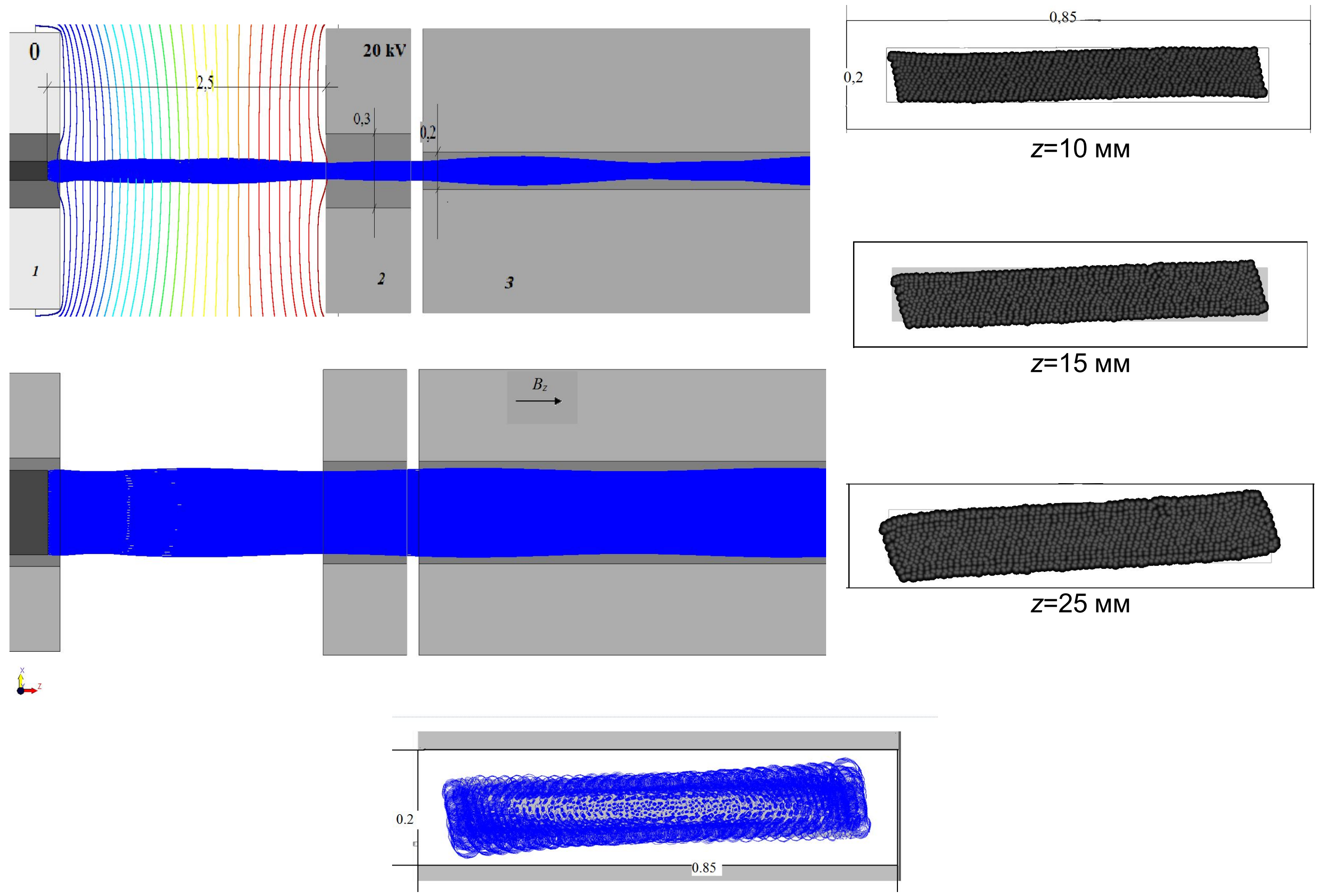

Figure 2. The calculation of EOS with sheet electron beam in uniform magnetic field (B_z = 1,12 T), 1 – cathode and focusing electrode, 2 – anode, 3 – slow-wave structure. Cross-sections of sheet electron beam at the different distances from the cathode

The magnetic field of 1,12 T has been selected from the numerical experiment, considering the influence of initial thermal transverse velocities of electrons, at the height fill factor of 0,8. Respectively the thickness of electron beam was 0,16 mm. The maximum angle of deformation of electron beam Θ at the distance of 25 mm from the cathode is 5,8°. Cyclotron radius of electron trajectories at the boundaries of beam in a uniform magnetic field at the distance of 25 mm does not exceed 15 μm.

Thus there is a possibility to design of EOS of sub-THz vacuum amplifier with sheet beam (with current of 70 mA and anode voltage of 20 kV) having a small deformation in a magnetic field with a distance of slow-wave structure is 25 mm.

References

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