Electron beam current limits in the drift tubes of terahertz vacuum devices

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The absence of powerful efficient and compact sources of radiation is the main obstacle in the development of the subterahertz and terahertz ranges (0.1–3 THz). Therefore, the creation of compact amplifiers and generators with powers of the order of units – thousand watts is the main task when advancing into the terahertz range. The most promising compact devices for producing high-power terahertz radiation at the present time are electrovacuum microwave devices. The output power of such devices depends on the power of the electron beam and the efficiency of its conversion into electromagnetic. Since the requirement of compactness of the devices limits the amount of accelerating voltage used, the main way to increase the power of the electron flow is to increase its current strength.

On the other hand, for effective interaction of the electron flow with the electromagnetic fields of multi-gap resonators and decelerating systems of electrovacuum microwave devices, the radius of the passage channel must be less than a quarter of the working wavelength. Therefore, to obtain high operating currents due to the small size of the cross section of the transit channel in the sub terahertz frequency range, it is necessary to switch to the use of electron fluxes with high values of current density in the beam (more than 1000 A / cm2). This raises the question of what is the value of the limiting current of the electron beam, which can be carried out without loss through the transit channel of the terahertz electrovacuum device frequency range. For continuous axially symmetric electron beams, there is a fairly accurate analytical solution to the problem of finding the limit values of the current and potential sag. However, there is no such solution for ring electron beams.

In the work, an effective numerical model based on solving a boundary value problem for the non-linear Poisson equation is proposed, which allows to estimate the maximum vacuum current and other parameters of circular and ring electron beams in cylindrical transit channels with high accuracy. The first part of the paper presents the formulation of the problem and the description of a numerical model for calculating the limiting vacuum current, as well as a comparison with the already existing analytical formulas. In the second part of the work, the results of the study of the parameters of continuous and annular axially symmetric electron beams are presented: the values of the limiting currents, their densities, and potential sagging.