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HIGH-POWER TERAHERTZ CHERENKOV RADIATION IN OVERSIZED SLOW-WAVE STRUCTURE*

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Cherenkov-type electronic vacuum devices seem to be promising sources of high-power terahertz (0.3–3 THz) radiation. To create small-sized sources of high-power radiation on a mobile platform, it is necessary to use high-current electron beams with electron energy of up to 500 keV. At present, in a Cherenkov surface wave oscillator [1], radiation pulses with a power of 2.1 MW have been obtained in the frequency range of 0.319–0.349 THz. In this case, a slow-wave structure has an oversize parameter (the ratio of the diameter to the radiation wavelength) of 6.8. In the experiments, the authors [1] used an annular electron beam with a current of I_b = 2.3–3.6 kA generated in a diode at a voltage of U_d = 350–480 kV in a magnetic field B = 3.1 T.

For numerical simulation of various Cherenkov devices with axial symmetry, we develop a 2.5D hybrid electromagnetic code consisting of two parts. The electrodynamic part of the code based on the scattering matrix method is used to study the resonant properties of oversized sectioned slow-wave structures. Examples of using the electrodynamic program, including in the sub-terahertz frequency range, can be found in [2, 3]. The second part of the code is developed based on the PIC-method and is used to simulate the interaction of a tubular electron beam with an electromagnetic field of pre-calculated resonant modes with a high quality factor.

In this paper, we present the first results of numerical simulation of a Cherenkov surface wave oscillator in the terahertz frequency range using the developed hybrid code. The interaction of a tubular electron beam and an electromagnetic field near the π-type of oscillations of TM_{01} mode was investigated. The model used the condition of ideal conductivity of the slow-wave structure surface, i.e., radiation losses in the metal [1, 4] were not taken into account. This is the subject of further work.

In the calculations, we used a slow-wave structure diameter of 40 mm with a period of rectangular diaphragms of 0.34 mm. The number of diaphragms is 40. The tubular electron beam with the leading edge duration of 0.5 ns and the current of 5 kA was injected into the slow-wave structure. The electron energy in the slow-wave structure was about 420 keV, which corresponded to the diode voltage of about 430 kV. The electron beam was transported in a uniform magnetic field B = 3 T. The average beam radius and the thickness varied in the calculations. The ratio of the slow-wave structure diameter to the radiation wavelength was about 50.

Two main longitudinal resonances of TM_{011} and TM_{012} modes with the frequencies of 0.3678 and 0.3658 THz and Q-factors of 2464 and 622, respectively, were found in the electrodynamic calculation. During the beam-field interaction, by the time moment of 1.5 ns from the pulse start, the longitudinal modes are synchronized at a frequency of 0.3662 THz. The radiation bandwidth is no higher than 0.04%. Total radiation power in forward and backward directions is equal approximately to 100 MW. Average electron losses of the beam for the period of diaphragms due of to deposition on the slow-wave structure surface are 0.015%.

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