Computer Simulation of the Process of MWCG Operation Start in Case of Slow Growth of E-beam Current

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Abstract – Using the computer simulation we made comparison of two different operation modes of the Multiwave Cerenkov Generator (MWCG). First mode has place when the current front is extremely short (less than 1 ns). Second one is when current pulse has duration about 1 mks.

1. Introduction

The MWCG is oscillator based on Cerenkov's mechanism of electron beam –electromagnetic filed interaction. It can provide high power microwave output as shown in [1].

In the experiment described in [2] the electron beam current had duration about 1 mks and its maximum (on 15 kA level) was achieved at 0.2 mks after beginning. Under these conditions, the microwave generation pulse was appeared on top of current pulse and had duration about 50–70 ns.

The numeric simulation of MWCG operation with the long current pulse requires many computer resources. It is the cause that computer simulation in most cases uses the assumption about current pulse front duration. One assumes that it is very short (under 1 ns).

In this paper, we compare results obtained for two different forms of current/voltage pulses.

2. Problem definition

Let's consider the self-consistent dynamic of electromagnetic field and relativistic electron beam guided by uniform magnetic field through axial-symmetric electro-dynamic structure (EDS) (Fig. 1).

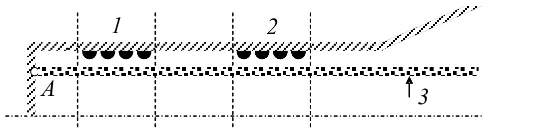

Fig. 1. Scheme of electrodynamic structure: *1*, *2* – first and second section respectively; *3* – electron beam.

The EDS contains two parts of corrugated circular waveguide with large (in comparison with wavelength of microwave radiation λ_0) diameter. The profile of heterogeneity is close to half-tore. The distance between nearest heterogeneities (period) is about $\lambda_0/2$. Each section contains 18–20 half-tores.

The energy and current of electron beam have time dependence represented by Fig. 2. It corresponds to experimental one [2].

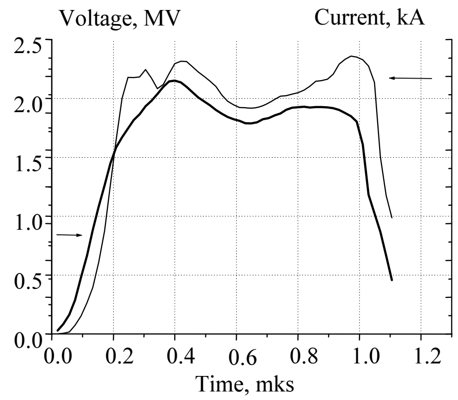

Fig. 2. Voltage and current of the electron beam

The self-consistent dynamic can be described by Maxwell's equations and motion equations of electrons. This equations system in axial-symmetry case is:

$$\frac{\partial E_r}{\partial t} = -c\frac{\partial H_\varphi}{\partial z} - 4\pi j_r; \qquad (1)$$

$$\frac{\partial E_z}{\partial t} = c\left(\frac{H_\varphi}{r} + \frac{\partial H_\varphi}{\partial r}\right) - 4\pi j_z; \qquad (2)$$

$$\frac{\partial H_\varphi}{\partial t} = c\left(\frac{\partial E_z}{\partial r} - \frac{\partial E_r}{\partial z}\right); \qquad (3)$$

$$\frac{dP^i_r}{dt} = q\left(E_r - \frac{v^i_z H_\varphi}{c}\right); \qquad (4)$$

$$\frac{dP^i_z}{dt} = q\left(E_z + \frac{v^i_r H_\varphi}{c}\right); \qquad (5)$$

$$\frac{dz^i}{dt} = v^i_z, \ \frac{dr^i}{dt} = v^i_r \qquad (6)$$

where c – speed of light in vacuum; P^i_j, v^i_j, z^i, r^i – components of impulse, speed and coordinates of i-th particle, q –its charge.

We modified and used numeric algorithm described in [3] for solving system (1–6).

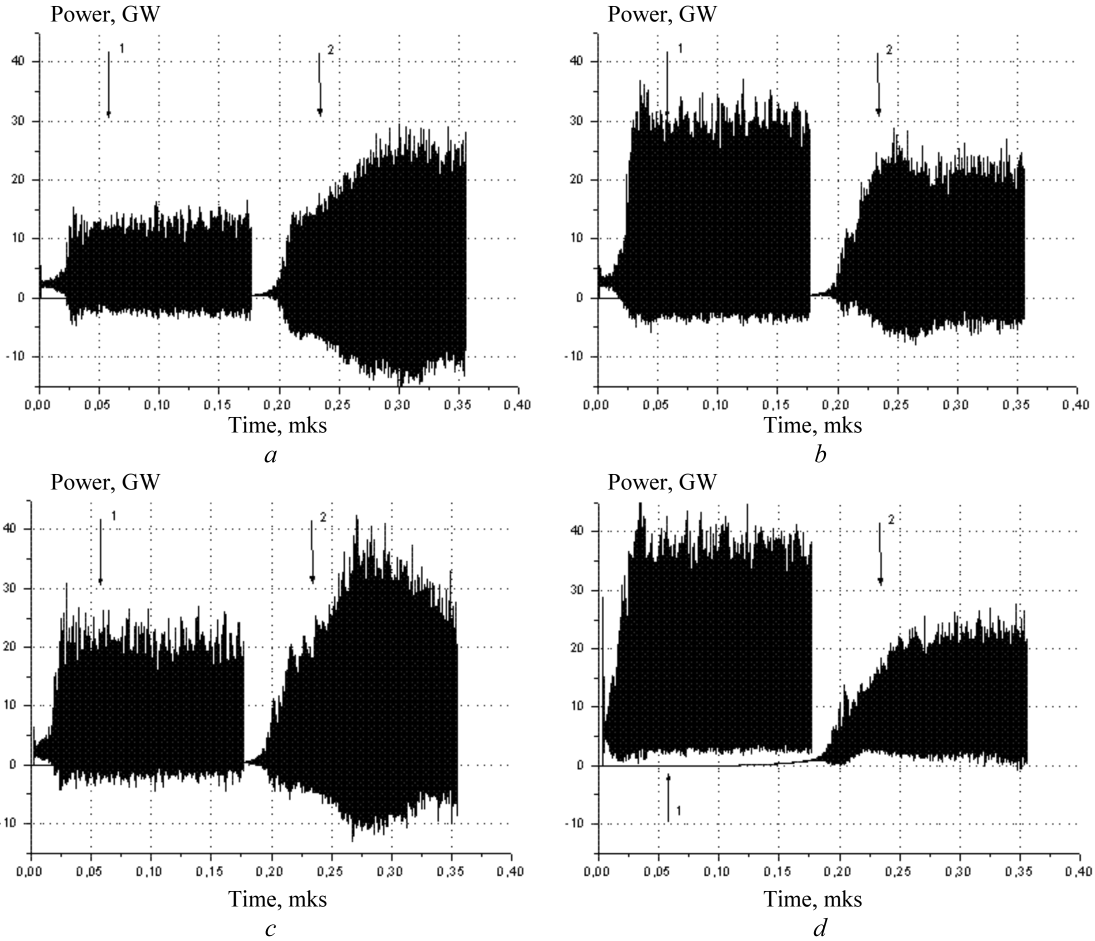

Fig. 3. Time dependence of power flow through middle of first section (*a*); drift tube (*b*); middle of second section (*c*) and output cross-section (*d*)

3. Results

In computer simulations, the leading magnetic field value equals 18 kGs.

Fig. 3 presents power flows for two cases: 1 – short beam current front; 2 – long one. We can see that the rates of rise high frequency oscillations in the first section of EDS are nearly equal to each other (Fig. 3, *a*). In case 2, significant growth of microwave power appears at the moment when beam current reaches its maximum value (about 2.1 mks after electron beam starts).

The behavior of power flows in other parts of the device is quite different. The power oscillations in second section (Fig. 3, *c*) are greater in case 2, but output power is smaller (Fig. 3, *d*).

On the base of the obtained results, it is possible to conclude that time length of the beam current front affects on the MWCG operation modes.

References

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