Orotron With Magnetic Nonuniformity – Advanced Millimeter Waves Source

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The millimeter waves Smith-Purcell effect oscillator - orotron with an non-uniform focusing magnetostatic field - is considered. The magnetic nonuniformity is shaped near the surface of slow-wave structure (grating) by means of the magnetic cylinder. In Fig.1 the scheme of the device is illustrated, where MN stands for the cross-section of the magnetic cylinder, which distorts the spatial distribution of a focusing field induction.

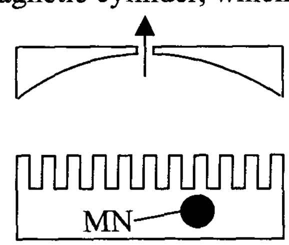

Figure 1.

The nonuniformity of a focusing field results in the appearance of transversal components of a magnetic displacement vector. Therefore, the electrons trajectories are distorted, too. Since the transversal allocation of the rf field is inhomogeneous (exponential damping from a grating surface), the efficiency of electronic - wave interaction will vary with the application of the non-uniform focusing field.

For the analysis of the physical processes in an orotron with magnetic nonuniformity the two-dimensional self-consistent theory has been developed. The investigation of different stages of the oscillations evolution has been carried out. In Fig.2 the dependences of a starting parameter value G (G is proportional to a beam current and quality-factor of a resonator) on the parameter $\Phi = \beta_e (1 - v_0/v)$ is presented, where $\beta_e = wL/v_0$, v_0 - initial velocity of electrons, ω - oscillation frequency, L - length of an interaction space, v - phase velocity of a slow wave. The dashed curve shows dependence for the device with a uniform focusing field. The curves 1-3 correspond to different values of the "range" of magnetic nonuniformity B/B_0, where B_0 - nonperturbed value of a focusing field induction, (-0.15, -0.25, -0.3, respectively). It is obvious, that the application of magnetic nonuniformity results in the change of the generator starting current and width of the generation zone . The curves 2,3 are plotted for the case, when all electrons settle on the grating. The increase of a starting current is stipulated by interaction space length shortening.

In Fig. 3 the results of the experimental research of an orotron with the non-uniform focusing field are represented. I_{st} is the normalized starting current, U - accelerating voltage (V). The dashed curve corresponds to the device with a uniform focusing field (B_0 = 0.4 Tesla). The

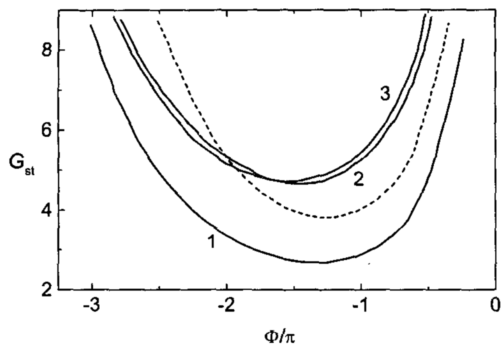

Figure 2.

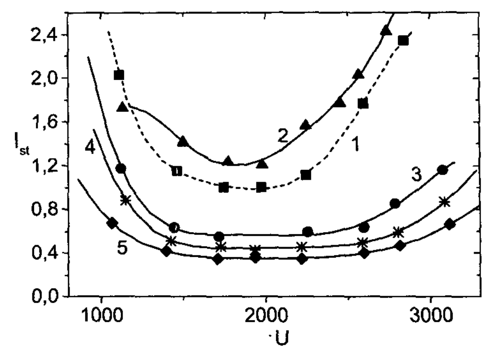

Figure 3.

curves 2-5 are plotted for different values of the focusing field induction in an orotron with magnetic nonuniformity (B_0 = 0.1, 0.16, 0.25, 0.4 Tesla, respectively). It is shown, that the device with the non-uniform focusing field can operate with smaller value of the focusing field induction. Moreover, in this case starting current is less than that in the device with usual focusing. The decrease of the B_0 results in the increase of the electrons settling on the grating and, as a result, to the increase of the starting current (curve 2). These results are in good agreement with the theory.

Fig. 4 shows the results of calculations of the electron efficiency of an orotron with magnetic nonuniformity in the steady-state mode. The dotted curve corresponds to a uniform focusing field. The dashed curves display unstable values of the oscillations amplitude. The curves 1-3 are plotted for different values of the magnetic nonuniformity center coordinate (0.4, 0.6, 0.8, respectively) and B/B_0 = -0.15. The application of a non-uniform focusing field results in the increase of an electron efficiency and generation zone extension.

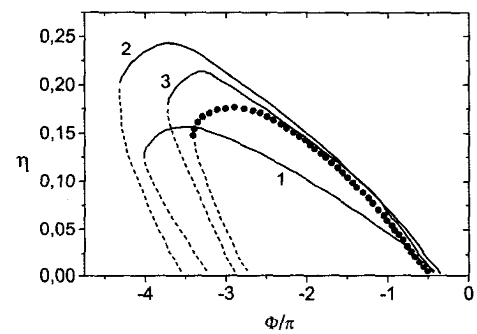

Figure 4.

It should be noted that the electrons settling on the grating results in the efficiency enhancement in the steady-state mode. This result can be explained by phase sorting of electrons, i.e. preferential settling of electrons which being in an accelerating phase of the rf field.

Table 1.

Device	I_{st}, mA	P, W	Δ , kHz	$\Delta\omega/\omega_0$
Orotron	36	5,2	25-40	$5\cdot10^{-7}$
Orotron - MN	18	8,0	5-25	$1\cdot10^{-7}$

In Tab.1 the data of the experimental investigations are represented. It is obvious that the application of a non-uniform focusing field is the perspective method of the improvement of amplitude and frequency characteristics of millimeter waves oscillators.