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Microwave oscillator - the orotron with the dc magnetic nonuniformity

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ABSTRACT

The effect of the profiled focusing magnetic field on the operation of the orotron is studied. The two-dimensional model of the beam-wave interaction is described. The decrease of the starting current and efficiency enhancement are possible for chosen theoretical model.

1. THEORETICAL MODEL

The longitudinal dc magnetic field (MF) is used in the vacuum microwave devices for focusing (TWT, orotron etc.) and beam phasing (magnetron, gyrotron etc.). Effect of the MF space distribution on the output characteristics may be significant. In the present work we consider the starting conditions and nonlinear characteristics of the orotron with localized magnetic nonuniformity (LMN). The modification of the MF space distribution results in distorsion of the electron trajectories and complex beam-wave interaction in the open resonator.

Self-cosistent nonlinear equations and their small-signal approximation are used for the theoretical study. The normalized MF longitudinal component dependence is approximated by the Gauss function in the LMN area[1]

$$B_{\parallel} = 1 + A_N \exp[-((y-y_N)/L_{WN})^2] \qquad (1)$$

where A_N, y_N, W_N - the LMN parameters; y - longitudinal coordinate; L - interaction space length. Combining Eq.(1) and divergence relation (divB=0) yields

$$B_{\perp} = (2A_N/(L_{WN})^2)(y-y_N)(z-z_N)\exp[-((y-y_N)/L_{WN})^2] \qquad (2)$$

where Z - transversal coordinate; z_N=const.

The longitudinal dc MF is intense enough so that the ripples of the electron beam boundaries can be neglected. Moreover, we assume LMN to be weak (i.e. $B_{\perp} << B_{\parallel}$).

2. DISCUSSION

Fig.1 illustrated the starting current dependence on the LMN center position. The dotted line gives I_{st} value in the case of uniform MF ($A_N = 0$). The dashed curves correspond to positive values of the parameter A_N. Positive and negative values of A_N indicate accordingly the enhancement and weakening of the MF in LMN area. In both cases the starting current decrease is achieved. Dependently on the A_N sign the LMN should be situated on the opposite grating ends. These results can be explained by transformation of the rf amplitude distribution in the beam frame. It is known that the variation of the amplitude distribution influences on the beam-wave interaction and in this manner the efficiency can be significantly enhanced[2].

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Fig.2 shows the maximum electron efficiency η (at values of the initial electron velocity for which the theoretical model has peak efficiency) as function of the parameter y_N for several values of the parameter A_N ($A_N<0$). All dependences are plotted at the fixed beam current. Dashed line gives the η value for usual uniform MF. Curve 1 corresponds to the case when interception of electrons by grating is absent. There is wide area of the y_N values where η is enhanced in comparison with the case when $A_N=0$. When the fraction of the electron beam is striking the grating, the LMN center should be situated on the interaction space end (curve 2 and 3). In this area the majority of the electrons being intercepted are in the region where bunches are located in phase position such that they are extracting energy from the wave. Thus, the interception results in phase selection of the electrons. The decrease of the accelerated electrons amount leads to widening of the initial electron velocity region where oscillations exist and electron efficiency enhancement.

3. CONCLUSIONS

Using the nonuniform focusing MF it is possible improve starting characteristics (starting current decreases) and enhance the efficiency of the orotron. The transformation of the rf amplitude distribution in the beam frame is the main mechanism of the starting current decrease. The enhancement of the electron efficiency is obtained due to phase selection of the electrons.,

4. REFERENCES

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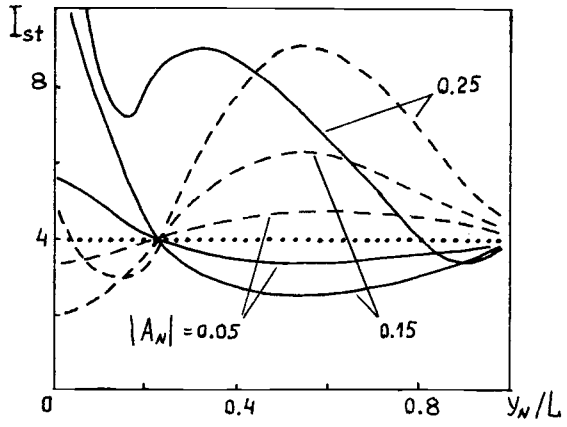

Fig.1. Starting current as a function of the parameter y_N/L.

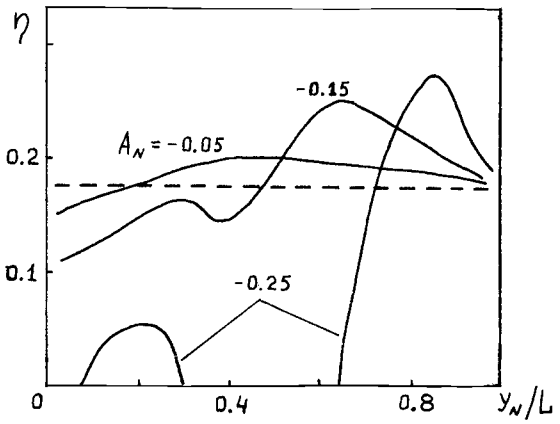

Fig.2. Efficiency vs y_N/L for different values A_N.