MODE COMPETITION OF THE GYROTRON UNDER HIGH EFFICIENCY OPERATING CONDITIONS

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Under high efficiency operating condition of the gyrotron, mode competition between the dominant mode and the lower lateral mode is almost unavoidable. In this paper, this sort of mode competition is studied by use of a set of non-linear self-consistent equations. Computation shows that there exists mode competition only in the common starting region of two modes and the starting currents calculated by single mode and multimode theories are in good agreement. Calculation shows, the mode interaction begins as soon as the amplitudes of the modes grow to some extent. The main effect of the mode competition is that the parasitic mode suppresses growth of the dominant mode.

Introduction

The reason why the gyrotron [1] based on the cyclotron resonance principle can operate in the millimeter wave band with high efficiencies is the "frequency selection" characteristic of the

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applied magnetic field. This "frequency selection" characteristic makes it possible to use interaction cavities operating at higher order modes. Thus the correlation between interaction structure dimensions and operating wavelength in traditional microwave tubes is overcome to a certain extent. However this brings a new problem: mode competition. As the cross section of the cavity becomes larger to increase the power capability of the gyrotron, the mode spectrum will be densified and the mode competition effect will be particularly serious.

As is known, an interaction cavity has a discrete spectrum of eigenfrequencies, and an applied magnetic field has a cyclotron resonance band. When the cyclotron frequency \( \Omega_0/\gamma_0 \) of electron rotating in the applied magnetic field \( B_0 \) and the eigenfrequency \( \omega \) of some mode in the cavity satisfy the following relationship

\[
\omega - s\Omega_0/\gamma_0 \geq 0
\]

where \( \Omega_0 = eB_0/m_0 \), \( \gamma_0 \) is the relativistic factor, \( s \) is the number of cyclotron harmonic, energy exchange between electrons and rf field will occur. For a certain cavity structure, different magnetic fields will make the cavity operate at different modes. This is called "frequency selection" characteristic of the applied magnetic field. If the cyclotron resonance band covers more than one eigenfrequency, there will possibly appear multimode oscillation in the gyrotron. Multimode operation has different disadvantages: for example, existence of parasitic modes widens the line spectrum of the output and different field distributions occur in the output. This is unwished for application of plasma heating; sharply decreasing of the interaction efficiency may cause excessive heating of the collector of the gyrotron; when the frequency of the parasitic mode is below the cut-off frequency of the gyrotron component, the energy trapped inside the gyrotron may cause arc. Therefore, it is necessary to study under what conditions multimode oscillation appears and can be avoided.