§ 25. Analysis of a Large Orbit Backward Wave Oscillator

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The effect of the finite azimuthal velocity component on the excitation of a backward wave oscillator (BWO) is investigated. The driver beam is assumed to be mono-energetic helical electron beam such that all the constituent electrons have their gyration centers on the axis of the slow wave structure (SWS). The beam supports negative energy fast and slow cyclotron modes (FCM and SCM) that can excite the structure modes in the SWS. This may contribute to enhance the microwave output from BWO, which has been limited to TM_{01} mode Cherenkov radiation. All the previous analyses on BWO have assumed the electrons without the initial perpendicular velocity component that is included in the present analysis for the first time. FCM and SCM can be negative energy waves, making the beam capable to transfer its energy to structure modes via cyclotron mechanism.

The first order RF perturbations in velocity and density in the thin annular large orbit beam are calculated. Integrating in radial direction across the beam, we derive the expressions for surface charge and current densities in terms of RF electric fields. The three boundary conditions on the beam surface are: (a) Matching of the discontinuous radial electric fields across the beam by the surface charge density. Matching of the discontinuous (b) azimuthal and (c) axial magnetic fields across the beam, respectively, by the axial and azimuthal components of the surface current density. Only two out of these three boundary conditions are independent. We therefore use (b) and (c). Augmenting these with the requirement of Floquet periodicity on the RF fields and the boundary conditions that the tangential electric field should be continuous on the beam surface and vanish on the metal SWS surface, $6(2N+1) \times 6(2N+1)$ order matrix is obtained. The determinant of it must be zero and this is the dispersion relation of the system. Here, $2N+1$ is the number of Floquet harmonics involved. Numerical analysis is made assuming $N=4$ and appropriate practical experimental parameters. Examples are shown in the figure below. The excitations of the unstable non-axisymmetric TE_{11} and TM_{11} modes in (c) and (d) caused by negative energy FCM in addition to unstable axisymmetric TM_{01} mode (BWO) in (a) and (b) caused by slow beam mode are observed. Grwoth rates of SCM in (e) and (f) are negligibly small.

Defining α as the ratio of the transverse to the longitudinal velocity components, it is found that, when $\alpha < 0.06$, the growth rate of conventional TM_{01} mode is predominant. For $\alpha \geq 0.06$, the growth rates of non-axisymmetric mode are dominant for the chosen set of parameters.