Numerical Analysis of Slow-Wave Instabilities in Oversized Sinusoidaly Corrugated Waveguide Driven by Finitely Thick Annular Electron Beam

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Backward wave oscillators (BWOs) are high power microwave sources and can be driven by an axially injected electron beam without initial perpendicular velocity. In such slow-wave devices, a slow-wave structure (SWS) is used to reduce the phase velocity of electromagnetic wave close to the beam velocity. In most experiments, the beam is guided by a magnetic field and has a thin-walled annular shape. With a finite strength guiding magnetic field, the beam modulates both in longitudinal and transverse directions. The theory including flowing beam in a finite strength magnetic field is still far from being fully elaborated. New versions of self-consistent field theory considering three-dimensional beam modulations are developed based on a solid cylinder beam with a finite strength magnetic field [1] and in the absence of magnetic field [2]. The effect of the transverse beam modulation appears as a surface charge at a fixed beam surface. For the finitely thick annulus, the beam boundaries are treated by the essentially same method as the solid cylinder beam, but the number of the boundary is different. The annular beam has outside and inside surface, and the solid beam has only outside surface. In Ref. [3], a linear theory with an annular beam having an arbitrary thickness is developed for a dielectric-loaded cylindrical waveguide. In order to increase the operation frequency and the power handling capability of BWO, periodically corrugated oversized SWSs are successfully used. The diameter is oversized in a sense that it is several times larger than free-space wavelength of output electromagnetic wave. Numerical studies for the oversized cases are required.

In this work, we develop a numerical code for a sinusoidaly corrugated waveguide with a finitely thick annular electron beam. The waveguide is oversized for K-band operations. And the normal modes of the system are analyzed numerically. The electromagnetic waves responsible for radiations are a surface wave localized near the waveguide wall. Instabilities due to the beam interactions with the surface wave are examined by considering three-dimensional perturbations at the beam boundaries. Slow cyclotron instability in addition to Cherenkov one occurs since transverse as well as longitudinal perturbations are included. We examine the dependence of growth rate on the annular thickness and guiding magnetic field.

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