Abstracts

The Linear and Self-Consistent Nonlinear Theory of the Electron Cyclotron Maser Instability

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In this paper the linear and nonlinear theory of the electron cyclotron maser instability is considered. The configuration used to study the maser instability consists of relativistic electrons gyrating about and drifting along a uniform magnetic field within a parallel plate waveguide. Relativistic effects associated with the gyrating electrons are responsible for excitation of the transverse electric mode in the waveguide. Linear theory shows that the growth rate maximizes when the axial beam velocity coincides with the axial wave group velocity of the excited electromagnetic wave. This allows us to perform the nonlinear analysis in a frame where both the axial wave number and axial beam velocity vanish. We have found that the maser instability exists only if the perpendicular beam energy exceeds a threshold value. Our analysis also describes the temporal nonlinear evolution of the field amplitude and frequency of a single excited wave. The nonlinear wave dynamics are self-consistently determined from the nonlinear particle orbits through the force and wave equations. The nonlinear analysis shows that there are two possible mechanisms for the saturation of the unstable wave: 1) depletion of the available free energy associated with the rotating particles and 2) phase trapping of the gyrating electrons in the wave. The initial beam parameters determine which of the two mechanisms is responsible for saturation. Competition between the two saturation mechanisms leads to a peaking in the energy conversion efficiency as a function of beam energy. Numerical results of the nonlinear formalism show that energy conversion efficiencies from the particles to the wave can be as high as 60 percent in the beam frame. Furthermore, by appropriately contouring the external magnetic field, among other things, efficiencies as high as 70 percent can be realized.

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