INFLUENCE OF FINITE RADIAL GEOMETRY ON COHERENT RADIATION GENERATION BY A RELATIVISTIC ELECTRON BEAM IN A LONGITUDINAL MAGNETIC WIGGLER

Ronald C. Davidson
Plasma Research Institute
Science Applications Inc.
Boulder, CO, 80302

Yuan-Zhao Yin
Plasma Fusion Center
Massachusetts Institute of Technology
Cambridge, MA, 02139

ABSTRACT

The influence of finite radial geometry on the longitudinal wiggler free electron laser instability is investigated for TE mode perturbations about a uniform density electron beam with radius $\hat{R}_b$. The equilibrium and stability analysis is carried out for a thin, tenuous electron beam propagating down the axis of a multiple-mirror (undulator) magnetic field $B_0(x) = B_0[1+(\delta B/B_0) \sin k_0 z]$, where $\lambda_0 = 2\pi/k_0$ const. is the wiggler wavelength. It is assumed that $k_0^2 B_0^2 << 1$, and that perturbations are about the self-consistent Vlasov equilibrium $f_b'(\xi, \nu) = (\hat{n}_b/\pi) \delta(p_{Lb}^2 - 2\gamma_b \nu_m \nu_b - 2\gamma_b \nu_b^2) \times \delta(p - \gamma_b \nu_b)$, where $p_{Lb}^2 = p_\perp^2 + p_\parallel^2$, $p_\parallel$ is the canonical angular momentum, and $\hat{n}_b$, $\gamma_b$, $\nu_m$, $\nu_b$, $\nu_b$, and $\nu_b$ are positive constants. For $\delta B/B_0 << 1$ and slow beam rotation ($\omega_b << \omega_m$), the equilibrium density is uniform ($\hat{n}_b$) out to the beam radius $\hat{R}_b = (2p_{Lb}/\gamma_b \nu_m \omega_b) ^{1/2}$. Detailed free electron laser stability properties are investigated for the case where the amplifying radiation field has TE-mode polarization with perturbed field components ($\hat{E}_0$, $\hat{B}_\phi$, $\hat{B}_z$). The matrix dispersion equation is analyzed in the diagonal approximation, and it is shown that the positioning of the beam radius ($\hat{R}_b$) relative to the conducting wall radius ($R_c$) can have a large influence on the growth rate and detailed stability properties. Analytic and numerical studies show that the growth rate increases as $\hat{R}_b/R_c$ is increased.

† Permanent Address: Plasma Fusion Center, Massachusetts Institute of Technology, Cambridge, MA 02139.

* Permanent Address: Institute of Electron, Academia Sinica, Beijing, People's Republic of China.