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Nonlinear analysis of two-stream free-electron laser amplifiers with axial guide fields

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ABSTRACT—**The effect of axial guide magnetic field on a saturation mechanism in a Two-Stream Free Electron Laser (TSFEL) has been studied by employing the two relativistic electron beams propagating through a helical wiggler field with different velocities. The relativistic electron streams are assumed to be cold. Self-consistent evolution of an electromagnetic wave in the presence of two electron beams is described by a set of coupled nonlinear differential equations in 1D approximation. Which slowly varying envelope approximation is used and by the Runge-Kutta method algorithm is solved numerically. The results of the calculations for the output power are presented as a function of the axial distance.**

KEYWORDS: Electromagnetic wave, Saturation mechanism, Two-Stream Free Electron Laser, Wiggler.

I. INTRODUCTION

There is great interest in utilizing two-stream free electron laser (TSFEL) to generate high-power, continuously tunable of coherent electromagnetic radiation [1-10]. It is results from the passage of two relativistic electron beams through a magnetic wiggler field that is spatially periodic along the beam axis [11-17]. Nonlinear theory of FEL with a helical wiggler pump in presence of different focusing mechanism has been investigated in [18-23]. In TSFEL no calculation has been reported. The purpose of the present paper is to investigate of saturation mechanism of TSFEL with a helical wiggler pump and an axial guide magnetic field.

II. THEORETICAL MODEL

A. The electric and magnetic fields

Two transversely homogeneous non-neutralized relativistic electron beams with different velocities $v_1$and v_2 propagate along the positive z direction trough the magnetic wiggler field, given by

$$\vec{B}(z) = B_0\hat{e}_z + B_w\left[\hat{e}_x \cos(k_w z) + \hat{e}_y \sin(k_w z)\right]. \quad (1)$$

Where $B_w$is the wiggler field amplitude, $k_w = 2\pi/\lambda_w$is the wiggler wave number, λ_w being wiggler period, $\hat{e}_x$, $\hat{e}_y$and $\hat{e}_z$ are the unit vectors of a Cartesian coordinate system. Here B_0 is a solenoidal guide magnetic field.The fluctuating electromagnetic fields and electrostatic fields are treated using the vector and scalar potentials in the Coulomb gauge, and we assume that these fields are of the form [21, 23]

$$\delta\vec{A}(z,t) = \delta\hat{A}(z)[\hat{e}_x\cos\alpha_+(z,t) - \hat{e}_y\sin\alpha_+(z,t)], \quad (2)$$

$$\delta\emptyset(z,t) = \delta\hat{\emptyset}(z)\cos\alpha(z,t). \quad (3)$$