A Numerical Study on Free-electron Laser Dynamics

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Abstract

Dynamics of Free-electron lasers(FEL) is investigated on the basis of the pendulum equations in the one-dimensional formulation. The phase-space evolution and the bunching coefficients of the electrons, which enable one to find the evolution of the radiation field, are briefly reviewed. Describing the computational procedures for solving the FEL pendulum equations numerically, we discuss the electron dynamics and the evolutions of the radiation field in the various gain regimes and the saturation regimes. Also we carried out numerical studies on the inhomogeneous broadening effects due to the energy spread and emittance of an electron beam.

Figures

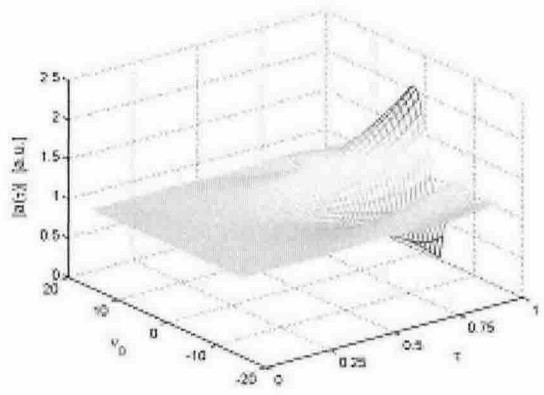


Figure 1. Amplitude of the FEL radiation fields $|a(\tau)|$ versus τ and ν_0 for a perfect electron beam at $j_0 = 15$.

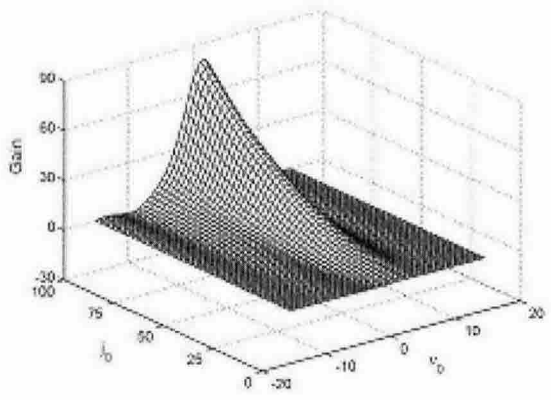
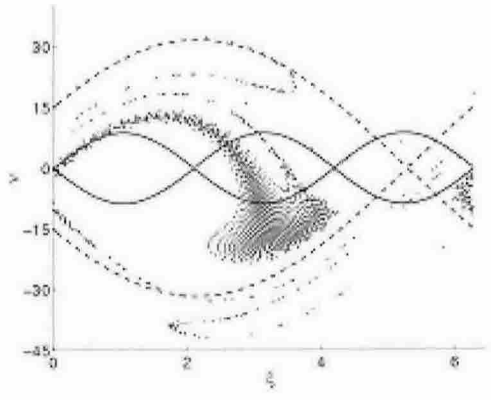


Figure 2. The FEL Gains ν_0 versus j_0 for a perfect electron beam.



Firgure 3. The electron dynamics in the phase space for the case of the saturation with a high gain FEL.

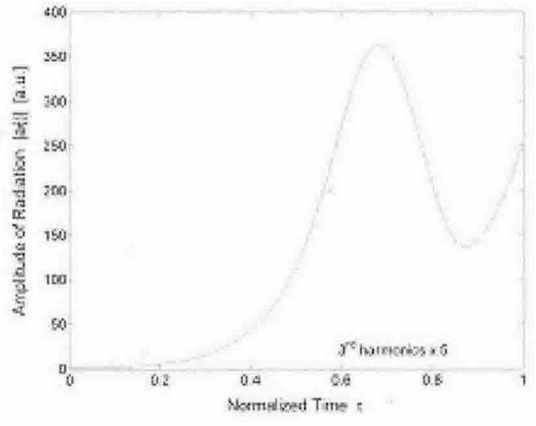


Figure 4. The evolution of the amplitudes of the radiation fields are plotted in the solid curve(the fundamental mode) and the dotted curve (the 3rd harmonic mode).

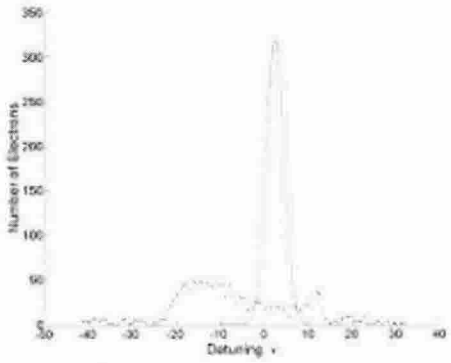


Figure 5. The electron distribution in the momentum space at the end of the FEL undulator. The initial distribution is plotted in the dotted curve.

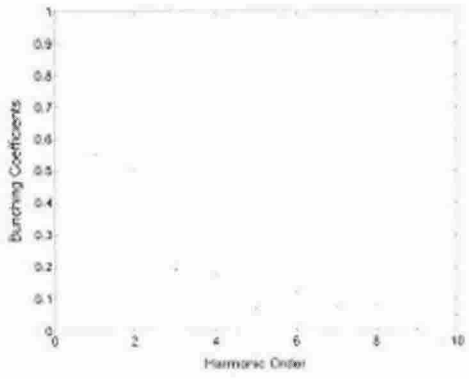


Figure 6. The bunching coefficients at the end of the FEL undulator vs. harmonic orders.

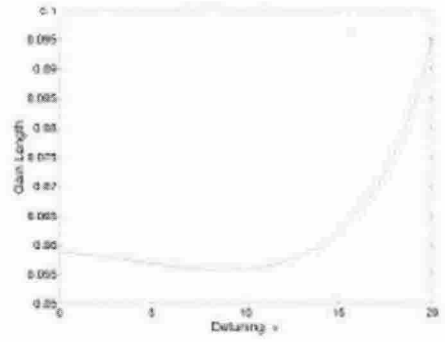


Figure 7. The electron gain per unit length vs detuning parameter ν_0. Computations are carried out in the regime of the rapidly growing radiation field occurring around the middle of the undulator.

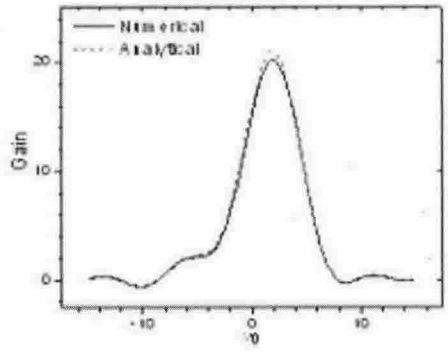


Figure 8. Comparison of numerical and analytic values of the FEL gain for a perfect electron beam at $j_0 = 50$.

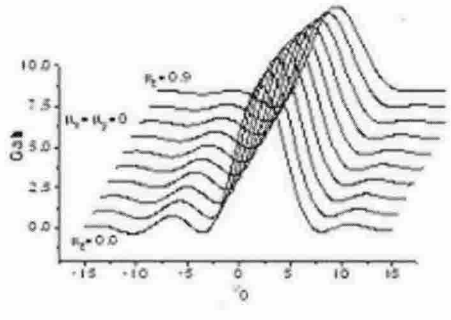


Figure 9. The FEL gains versus ν_0 for various energy spread parameters μ_ε at $j_0 = 30$.

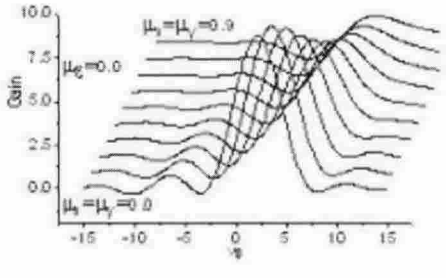


Figure 10. The FEL gains versus ν_0 for various emittance spread parameters μ_y at $j_0 = 30$.