The Electromagnetic Darwin Model for Intense Charged Particle Beams*

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The theoretical and numerical properties of the electromagnetic Darwin model [1] for intense charged particle beams are investigated. The model neglects the transverse displacement current in Ampere's law and results in the elimination of high-frequency transverse electromagnetic waves and the associated retardation effects in the Maxwell-Vlasov equations. In this paper, two numerical schemes are presented for the purpose of circumventing the numerical instabilities associated with the presence of $\mathbf{E}^T(\equiv \partial\mathbf{A}/\partial t)$ in the equations of motion for particle codes [2], where $\mathbf{A}$ is the vector potential. The first relies on higher-order velocity moments for closure [3,4], and the other replaces the mechanical momentum, $\mathbf{p} = \gamma m\mathbf{v}$, by the canonical momentum, $\mathbf{P} = \mathbf{p} + (q/c)\mathbf{A}$, as the phase-space variable [2]. The properties of these simulations schemes in the laboratory frame as well as in the beam frame are also discussed. These new numerical methods are most suitable for studying Weibel [5] and two-stream [6] instabilities in heavy ion fusion research.

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