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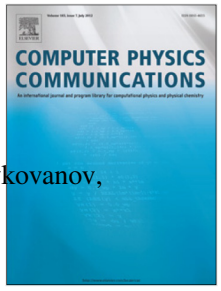

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A Systematic Approach to Numerical Dispersion in Maxwell Solvers

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Abstract

The finite-difference time-domain (FDTD) method is a well established method for solving the time evolution of Maxwell's equations. Unfortunately the scheme introduces numerical dispersion and therefore phase and group velocities which deviate from the correct values. The solution to Maxwell's equations in more than one dimension results in non-physical predictions such as numerical dispersion or numerical Cherenkov radiation emitted by a relativistic electron beam propagating in vacuum.

Improved solvers, which keep the staggered Yee-type grid for electric and magnetic fields, generally modify the spatial derivative operator in the Maxwell-Faraday equation by increasing the computational stencil. These modified solvers can be characterized by different sets of coefficients, leading to different dispersion properties. In this work we introduce a norm function to rewrite the choice of coefficients into a minimization problem. We solve this problem numerically and show that the minimization procedure leads to phase and group velocities that are considerably closer to c as compared to schemes with manually set coefficients available in the literature. Depending on a specific problem at hand (e.g. electron beam propagation in plasma, high-order harmonic generation from plasma surfaces, etc), the norm function can be chosen accordingly, for example, to minimize the numerical dispersion in a certain given propagation direction. Particle-in-cell simulations of an electron beam propagating in vacuum using our solver are provided.

1. Introduction

The finite-difference time-domain (FDTD) method is widely used for the simulation of electromagnetic wave propagation in different scenarios ranging from the simulation of antennas to astrophysical problems [1]. It is also the standard method to solve Maxwell's equations in particle-in-cell (PIC) simulations, where plasma, represented by macroparticles, and electromagnetic fields are treated in a self-consistent manner [2]. In the traditional FDTD method, also

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