Editorial

Electromagnetic Simulation

Electromagnetic simulation is important to many areas of plasma and beam physics, specifically including laser-plasma interaction, astrophysics, tokamak heating, particle accelerators, and microwave devices. A widely-used approach to electromagnetic simulation for plasma and beam applications is finite-difference time-domain simulation (FDTD), an approach that is nearing its fiftieth year of application. FDTD is especially popular in high-performance computing because the technique scales naturally to large numbers of distributed processors.

However, FDTD has a number of limitations that are areas of active research in the computational plasma physics community. The rectangular grids used in many FDTD simulations can be an inadequate for representing curved surfaces, resulting in inaccuracies in the fields both spatially and temporally. Also, the time step in the standard approach to electromagnetic FDTD simulations is often limited by the restriction that a light wave not cross a computational grid cell in one time step. Boundaries are another common challenge for FDTD simulation. This includes physical boundaries, for instance such as boundaries between vacuum and dielectric, especially if the dielectric material is described by complex material constants, and computational boundaries, for instance at the boundaries of the finite-difference grid. Finally, the presence of a beam or plasma in an FDTD simulation presents even more challenges. For example, another limit on the time step can be the gyro-radius of electrons in the presence of external fields. Also, cold and dense plasmas are especially challenging, as the Debye length of these plasmas can force the spatial grid to be smaller than is computationally feasible.

Recently, researchers have made advances to FDTD simulation to help address these shortcomings, including more accurate models of embedded boundaries, more robust algorithms for large time stepping, better algorithms for advancing particles in strong magnetic fields, improved models of materials with complex material properties, better algorithms for outgoing waves on the boundaries of the computational domain in the presence of charged particles, a new approach for modeling a vacuum-dielectric interface on scales smaller than a wavelength of the electromagnetic wave, and code-to-code benchmarking of cold, dense plasma models. The articles in this special issue will discuss these advances and the plasma physics research they have have made possible.

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