Particle-in-Cell Simulations of ICRF Wave-Particle Interaction

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Abstract

When nonlinear effects come into play, traditional, linear RF theory becomes invalid. An example of when this can occur is during coupling of ICRF waves (e.g. IBWs). Because of the low densities and temperatures at the plasma edge, the wave energy density in front of an antenna can greatly exceed the plasma energy density. In this region, ponderomotive and other nonlinear effects can significantly affect the antenna-plasma coupling.

The Particle-in-Cell (PIC) algorithm [1] directly solves the coupled set of Maxwell's equations and the equations of motion for a distribution of macroparticles (representing the real particles). Because few approximations are made the relevant nonlinear physics is retained and reproduced by PIC simulations. The directness of the PIC approach does however make it computationally demanding; small timesteps and many macroparticles are necessary for converging the solution.

To make PIC simulations (of coupling or other phenomena) over many ion gyroperiods feasible, it is necessary to use algorithms that remove the fastest, physically uninteresting timescales. We have modified the PIC code VORPAL [2] so that the timestep is no longer limited by neither the Courant condition nor the electron gyroperiod.

The removal of the Courant condition was achieved by implementing the implicit field solver of Bowers [3]. The Bowers scheme uses modified versions of Faraday's and Ampere's laws where damping is directly included in the curl terms. Bowers shows that after Crank-Nicholson time discretization the level of damping corresponds directly to the degree of implicitness. I.e., as the damping parameter is increased, the discretized equations go from fully explicit to fully implicit.

The electron gyroperiod is three orders of magnitude shorter than the timescale of interest: the ion gyroperiod. By replacing the electron equation of motion with its gyrocenter counterpart, the physically uninteresting electron gyration is removed while the physically important electron Landau damping is kept.

We have also implemented a simple antenna model in VORPAL to allow us to perform coupling simulations.

We will describe the algorithms we have used to remove the fastest timescales and to make VORPAL a tool for direct simulations of ICRF wave-particle interaction. Preliminary results will be presented.

[1] C. K. Birdsall and A. B. Langdon, *Plasma Physics via Computer Simulation*, (IoP Publishing, Bristol, 1991).

[2] C. Nieter and John R. Cary, "VORPAL: a versatile plasma simulation code", to be published in J. Comp. Phys.

[3] K. J. Bowers, "Implicit methods of solving the Maxwell equations suitable for particle-in-cell simulation of low temperature plasmas", submitted to J. Comp. Phys.