AN ARBITRARY CURVILINEAR COORDINATE PARTICLE-IN-CELL METHOD*

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We present a new approach to the kinetic simulation of plasmas in complex geometries, based on the Particle-in-Cell (PIC) method. In our method, called the Arbitrary Curvilinear-Coordinate PIC (ACC-PIC) method, all essential PIC operations are carried out on a two-dimensional uniform, unitary square logical domain and mapped onto the nonuniform, boundary-fitted physical domain.
We have utilized a grid generation technique known as Winslow's method [1] to generate boundary-fitted physical domains. The logical grid macroparticle equations of motion have been derived through a canonical transformation of Hamilton's equations from the physical domain to the logical. The resulting equations are non-separable, and therefore not amenable to being integrated with the standard Leapfrog method. We have developed an extension of the semi-implicit Modified Leapfrog (ML) integrator [2] to preserve the symplectic nature of the logical grid mover. We have constructed a generalized, curvilinear coordinate formulation of Poisson's equations to solve for the electrostatic fields on the uniform logical grid. By our formulation, we supply the plasma charge density on the logical grid as a source term. By the formulations of the logical grid particle mover and the field equations, the plasma particles are weighted to the uniform logical grid and the self-consistent mean fields obtained from the solution of the Poisson equation are interpolated to the particle position on the logical grid. This process eliminates the complexity associated with the weighting and interpolation processes on the nonuniform physical grid.
In this presentation, we discuss the individual components of the ACC-PIC method, then present several standard physics tests to validate the accuracy of our 2D code for both orthogonal and nonorthogonal nonuniform grids in comparison with a standard uniform grid PIC code. Finally, as a proof of principle, we show the time evolution of an electrostatic plasma oscillation in an annular domain obtained using Winslow's method.

1. A. Winslow, J. Comp. Phys., vol 1, p. 149, 1967
2. J.M. Finn and L. Chacon, Phys. Plasmas, vol. 12, p. 054503, 2005

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