Lorentz Ion Orbit Averaging and Numerical Analysis of $\delta f$ Methods

Benjamin Sturdevant$^{1,2}$, Scott E. Parker$^2$, and Yang Chen$^2$

$^1$Department of Applied Mathematics, University of Colorado at Boulder, Boulder, Colorado 80309, USA
$^2$Department of Physics, University of Colorado at Boulder, Boulder, Colorado 80309, USA

benjamin.sturdevant@colorado.edu

A second order, implicit Lorentz ion drift/gyrokinetic electron model is presented which has been developed to study low-frequency, quasi-neutral plasmas [1],[2]. This model may be useful, for example, as a viable alternative to gyrokinetics in the tokamak edge region where gradient scale lengths are short. The applicability of the model is limited in the presence of a strong guide field, however, due to the time step size requirements for fully resolving the ion gyromotion. The aim of this research is to develop GPU accelerated sub-cycling and orbit averaging methods that can be used with the Lorentz ion model to help make its utilization more viable. Sub-cycling pushes computational particles independently over several micro time steps for each macro time step interval over which the fields are advanced. Orbit averaging uses the deposition data from the sub-cycled particles to obtain time averaged source terms used in the field solving stage. This provides a filtering effect, allowing for clean simulations at low frequencies.

Additionally, the numerical accuracy and stability of warm plasma $\delta f$ PIC simulation will be analyzed including both finite time step and finite grid size. This analysis is similar to what was developed in [3] and [4] for full-f PIC. The time integration analysis, however, requires a different approach and is performed using a discrete version of the method of characteristics applied to the $\delta f$ particle weight equation. A numerical dispersion relation including effects of a finite time step and spatial grid for an implicit $\delta f$ ion acoustic model is derived. Stability results for $\delta f$ PIC are presented and comparisons are made with an implicit full-f model.