Fully implicit spectral method for the solution of the Vlasov equation based on Hermite polynomials

Gian Luca Delzanno\textsuperscript{1}, E. Camporeale\textsuperscript{2}, J. David Moulton\textsuperscript{1}, Benjamin Bergen\textsuperscript{1}, B. Srinivasan\textsuperscript{3} and Gianmarco Manzini\textsuperscript{1}

\textsuperscript{1}Los Alamos National Laboratory, Los Alamos, New Mexico, USA
\textsuperscript{2}CWI, Amsterdam, Netherlands
\textsuperscript{3}Virginia Tech, Blacksburg, Virginia, USA

delzanno\_at\_lanl.gov

We discuss a spectral method to solve the Vlasov-Maxwell equations for collisionless plasmas, by means of an expansion of the distribution function into a Fourier-Hermite basis [1,2] which reduces the Vlasov equation to an infinite system for the moments of the expansion. Previous Hermite-based approaches [2] used an explicit time integrator scheme which did not conserve the total energy in the system (for periodic boundary conditions). With a fully-implicit time integrator, we show that the Fourier-Hermite method can instead conserve charge, momentum, and energy exactly. On the other hand, currently no PIC code is able to conserve these three quantities simultaneously. The nonlinear system for the moments of the expansion is then solved numerically with a Jacobian Free Newton-Krylov solver with GMRES for the inner krylov iterations.

In the one-dimensional electrostatic limits, we present results for several cases routinely used as benchmarks in computational plasma physics: Langmuir wave, Landau damping, two-stream instability, ion-acoustic wave and plasma echoes. It is shown that the Fourier-Hermite method can achieve a much more accurate solution in a tiny fraction of the computational time relative to PIC, with orders of magnitude higher efficacy (a measure of the cost-effectiveness of the algorithm) [3,4].

Multi-dimensional fully electromagnetic tests involving high frequency plasma waves and the whistler instability will also be presented. In multi-dimensions preconditioning strategies become crucial to maintain the scalability of the algorithm as the dimension of the Krylov space increases. We present two preconditioning strategies showing that an order of magnitude decrease in the Krylov iterations and a sizeable gain in code speed-up can be achieved.