Acceleration of Particle-In-Cell Schemes using a Sparse Grid Approach

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The Particle-In-Cell (PIC) scheme is one of the most effective for discretizing kinetic models. However, it requires prohibitive execution time for the simulation of plasma devices in real conditions. In explicit schemes, when particles are advanced with fields known at previous time steps, severe constraints exist to avoid numerical heating (see [1], [2]). The grid mesh spacing and time step must resolve the electron properties leading to severe constrains at high densities. The accuracy of the results is also correlated with the number of particles used in the simulation which can demand tremendous CPU and memory resources, even on super-computers.

The introduction of a sparse grid in the discretization of a problem with high dimensionality was proposed in the 1960s to solve the constraints related to the memory size of computers. It is based on the use of a hierarchy of grids with increasing resolution. The different numerical approximations performed on each of them allow the reconstruction of the solution on a refined grid with very good precision and extreme efficiency. The use of sparse grids combined with the PIC approach offers a reduction in the total number of particles for the same statistical error as the standard regular grid approach, and hence a speedup in computational time [3]. Ricketson and Cerfon have shown the applicability of sparse grid PIC schemes in the context of Landau damping and diocotron instability [4]. We have recently revisited this method and extended it to new applications [5], [6]. We will present comparisons between the standard and sparse PIC algorithms in the context of low-temperature plasmas.

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