Development of a multi-scale PIC code using AMR and its MPI parallelization

Hideyuki Usui¹, Tatsuki Matsui¹, Toseo Moritaka¹, and Masanori Nunami²

¹Graduate School of System Informatics, Kobe University, Kobe, 657-8501, Japan
²National Institute for Fusion Science, Toki 509-5292, Japan

tmatsui at hawk. kobe - u.ac. jp
moritaka.toseo at cs. kobe - u.ac. jp

Our research target is to investigate electromagnetic interactions between the solar wind and a small-scale dipole field artificially created with a superconducting coil on spacecraft. The typical size of the dipole field will be comparable to the ion inertial length or less. Therefore we need kinetic treatment both for electrons and ions to investigate the interaction process. To examine the interactions which occur in a large spatial scale covering from the ion inertial length to spacecraft size, we need to introduce multi-scale treatment in kinetic simulations. For this purpose, we have started developing a new PIC simulation code by using adaptive mesh refinement (AMR).

One difficulty of AMR technique is the exchange of physical information between hierarchical domains with different grid sizes and time step intervals. In order to handle this problem, an overlap region is produced at the interface, and time evolutions of electromagnetic field and super particles with optimal shape factors are evaluated in both grid systems[1]. This interface scheme is validated by the test simulations on wave propagation and plasma instabilities.

In addition, our ongoing effort to port the AMR-enabled 3D PIC code onto distributed environments is introduced. In AMR, complicated cell arrangements are organized and managed as interconnected pointers with multiple resolution levels, forming a fully threaded tree data structure as a whole[2]. We report the project overview and the current progress, such as the methods of interprocess data transfer and domain decomposition, that are devised for the parallelization of the AMR scheme. Using this advanced simulation code, preliminary results for basic physical problems are exhibited, together with the benchmarks to test the performance and the scalability.