Relativisitc intense beam solid interactions: a ‘comprenhensive’ simulation framework

Dong Wu

Institute for Fusion Theory and Simulation, Zhejiang University

Abstract: Beam-solid interaction is of great importance to a lot of applications, like inertial confinement fusion, high energy density science, laser driven particle acceleration and laser/beam driven light sources. However, the direct numerical simulation of intense beam-solid interactions is still of great challenges, because of the many coupled atomic and plasma processes, such as ionization dynamics, collision among charged particles, and collective electromagnetic fields, to name just a few. Here, we develop a new particle-in-cell (PIC) simulation code, which enables us to calculate beam-solid interactions in a more realistic way.

This code is able to cover almost “all” the coupled physical processes. This code incorporates both, the ionization and collision dynamics within the plasma on similar footings. Within the simulations, the ionization charge state of targets could evolve according to the local plasma and electromagnetic fields conditions. Different types of targets composed of quite different components can now be modelled based on their intrinsic atomic properties.

Moreover, a high order implicit multi-dimensional particle-in-cell (PIC) method is developed for simulating plasmas at solid densities. The field solver algorithm completely eliminates numerical instabilities found in explicit PIC methods with relaxed time step and grid resolution. Moreover, this algorithm eliminates the numerical cooling found in the standard implicit PIC methods, by using a pseudo electric field method. The particle pusher algorithm combines the standard Boris’ particle pusher with Newton-Krylov iteration method. This algorithm increases the precision accuracy by several orders of magnitude when compared with standard Boris’ particle pusher, and also significantly decreases the iteration time when compared with pure Newton-Krylov method.

This code was extensively benchmarked with experiments, for example the laser drive ion acceleration experiment conducted at Peking University.