Laser wakefield acceleration modeling based on ponderomotive guiding center solver using particle-in-cell code OSIRIS

A. Helm¹, J. Vieira¹, L.O. Silva¹, R.A. Fonseca¹²

¹ GoLP/IPFN Instituto Superior Técnico, Universidade de Lisboa, Lisboa, Portugal
² Instituto Universitário de Lisboa (ISCTE-IUL), Lisboa, Portugal

Laser wakefield acceleration (LWFA) is currently seen as a potential candidate for a future generation of particle accelerators due to its compactness and ultra-high acceleration gradients. The main tool for the numerical modeling of LWFA is the Particle-in-cell (PIC) algorithm. However, PIC simulations are computationally expensive, especially due to the large disparity of the relevant scales, ranging from the laser wavelength $\lambda_0$ (~1 μm) to the acceleration distance (~10-100 cm). Reduced simulations using the ponderomotive guiding center (PGC) algorithm [1, 22] are a promising approach to reduce the computational requirements of LWFA simulations by orders of magnitude. The PGC algorithm models the evolution of the laser envelope, and requires only scales associated with the plasma skin depth $\lambda_p$ to be resolved, leading to speedups of $\sim(\lambda_0/\lambda_p)^2$. Here we present the implementation of the 3D version of a PGC solver into the massively parallel, fully relativistic particle-in-cell code OSIRIS [3]. Previous work was focused around implementing a 2D [4] and 3D [5] version. Here we provide a condition stability of the algorithm, the extension of boundary conditions and the limitations of the algorithm in terms of maximum propagation distance allowed. In addition, we present details on the hybrid shared memory (OpenMP) and distributed memory (MPI) parallelization of the algorithm with incorporation of transversal parallel domains, and studies of the strong and weak scaling of the algorithm. Several applications, such as magnetic injection and design studies for LWFA scenarios are discussed, including detailed comparisons between 3D full-PIC and PGC simulations. This work was partially supported by Fundação para a Ciência e Tecnologia (FCT), Portugal, through grant no. PTDC/FIS-PLA/2940/2014.

References: