Breaking the Radiation Frequency Limit in PIC Codes

Miguel Pardal[1,†], Ricardo A. Fonseca[2,1], Jorge Vieira[1]

[1] *GoLP/Instituto de Plasmas e Fusão Nuclear, Instituto Superior Técnico, Universidade de Lisboa, Lisbon, Portugal*

[2] *DCTI/ISCTE Lisbon University Institute, 1649-026 Lisbon, Portugal*

[†] miguel.j.pardal@tecnico.ulsiboa.pt

Radiative processes in plasmas are ubiquitous in laboratory settings but also in astrophysics. Here, the radiation observed from space can provide crucial insights on the relevant physical mechanisms occurring under extreme conditions in the universe [1]. Radiation emission plasmas is often a result of collective effects associated with the dynamics of relativistic charged particles. A common numerical approach to model their motion involves the Particle-In-Cell [2] (PIC) scheme which solves the full set of Maxwell's equations and the relativistic Lorentz force for the charged particles. The recently developed Radiation Diagnostic for OSIRIS (RaDiO) [3] can retrieve the emitted spatiotemporal electromagnetic field structure of the emitted radiation in OSIRIS [4] simulations, even at wavelengths smaller than the PIC resolution, by relying on the Liénard-Wiechert Potentials [5]. OSIRIS can run with a high level of efficiency in most of the largest CPU-based supercomputers in the world [6]. Nevertheless, in recent years, GPU accelerator boards have been employed in supercomputers to the point where some of the most powerful machines nowadays are GPU-based systems. In these architectures, the CPU nodes are equipped with additional GPU boards that can be used to perform highly parallelizable computations such as obtaining the emitted radiation in a PIC code. In this work, we describe the implementation of the radiation algorithm in the GPU architecture and its integration into OSIRIS. Several performance benchmarks confirm the efficiency and applicability of this diagnostic for research in astrophysical plasmas.

References

[1] The Event Horizon Telescope Collaboration. First m87 event horizon telescope results. i. the shadow of the supermassive black hole, 2019.

[2] J. M. Dawson, Particle simulation of plasmas, Reviews of Modern Physics 55 (2) (1983) 403-447. doi:10.1103/RevModPhys.55.403.

[3] M. Pardal, R. A. Fonseca, J. Vieira et al. RaDiO: an efficient spatiotemporal radiation diagnostic for particle-in-cell codes, submitted, 2022.

[4] R. A. Fonseca, L. O. Silva, F. S. Tsung, V. K. Decyk, W. Lu, C. Ren, W. B. Mori, S. Deng, S. Lee, T. Katsouleas, J. C. Adam, Osiris: A three dimensional, fully relativistic particle in cell code for modeling plasma based accelerators, in: P. M. A. Sloot, A. G. Hoekstra, C. J. K. Tan, J. J. Dongarra (Eds.), Computational Science – ICCS 2002, Springer Berlin Heidelberg, Berlin, Heidelberg, 2002, pp. 342-351.

[5] J. Vieira, M. Pardal, J. T. Mendonça, R. A. Fonseca, Generalized superradiance for producing broadband coherent radiation with transversely modulated arbitrarily diluted bunches, Nature Physics 17 (1) (2021) 99-104. doi:10.1038/s41567-020-0995-5.

[6] R. A. Fonseca, J. Vieira, F. Fiúza, A. Davidson, F. S. Tsung, W. B. Mori, L. O. Silva. Exploiting multi-scale parallelism for large scale numerical modelling of laser wakefield accelerators, Plasma Physics and Controlled Fusion, 55(12) (2013)