Machine learning controlled laser wakefield acceleration simulations

B. Malaca[1], J. Vieira[1], R. Fonseca[1,2]

[1] *GoLP/Instituto de Plasmas e Fusão Nuclear, Instituto Superior Técnico, Universidade de Lisboa, 1049-001, Lisbon, Portugal*

[2] *DCTI/ISCTE-Instituto Universitário de Lisboa, 1649-026 Lisbon, Portugal*

One of the most promising technologies to form the next generation of compact particle accelerators is plasma acceleration. Plasmas have the ability to sustain waves with electric fields that can be 3 orders of magnitude higher than those in radio frequency (RF) cavities.

The ultimate goal of plasma-based acceleration is to produce relativistic, high quality electron and positron bunches for scientific and societal applications. The recent progress has been tremendous but improving beam quality still remains as a grand-challenge in the field.

The fundamental aspects and properties of these accelerators are accessible through simplified analytical models, but the self-consistent dynamics of the laser in the plasma can only be captured by numerical simulations. Search for optimised parameters to improve beam quality can be based on systematic parameter scans. However, because numerical calculations can be very computationally intensive, it is important to investigate more efficient techniques to scan over the entire parameter range currently available. In this work, we propose a machine learning approach to optimize this search based on genetic algorithms.

Recent experiments have employed genetic algorithm to control plasma based accelerators [1]. Here, instead, we will employ this technique to control the outputs and optimise plasma-based accelerators. We implemented a genetic algorithm in ZPIC, a fully relativistic particle-in-cell educational code[2]. The algorithm is fully automated: it creates an initial set of input parameters, launches several simulations in parallel, and ends automatically once given convergence criteria are reached. The algorithm can thus take full advantage of large-scale supercomputers. We present results from both 1D and 2D simulations. In 1D, we focus on plasmas with non-uniform density and lasers with variable longitudinal envelope profiles. In 2D we also consider the role of distorted wave-fronts in the acceleration. We present optimisation studies of laser plasma accelerators, towards bunches with high quality in terms of efficiency and phase-space properties (e.g. energy spread, divergence). Our algorithm is general, and can be readily applied to any other class of optimisation problems in plasma physics.

References

[1] Z.-H. He, B. Hou, V.Levailly, J. Nees, K. Krushelnick and A. Thomas, Nature communications, **6** (2015)

[2] `https://github.com/zambzamb/zpic/`