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P5.2021 Genetic algorithm controlled 2D laser wakefield acceleration simulations

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One of the most promising technologies to form the next generation of compact particle accelerators is plasma acceleration, providing accelerating distances up to 3 orders of magnitude shorter than conventional accelerators. Recent progress has been tremendous but improving beam quality still remains as a grand-challenge in the field, as numerical simulations remain the only way to capture all self-consistent dynamics of the laser and plasma. Beam quality often depends on specific aspects of the plasma density and laser pulse profiles, which cannot be retrieved by purely analytical models alone, thus requiring extensive parameter scans, which can be very expensive computationally. Here we show a technique that can be used to reduce the computing time required to determine the optimal conditions to control and optimize specific properties of the accelerated beams.
Recent experiments employed genetic algorithms to control plasma-based accelerators [1]. Here, instead, we will employ this technique to optimize accelerators from laser wakefield simulations. We implemented a genetic algorithm in ZPIC, a fully relativistic particle-in-cell educational code [2]. The algorithm is fully automated, launching several simulations in parallel. Some studies were already performed in 1D [3], but here we focus on the results from two-dimensional simulations. Specifically, we considered the role of aberrations on the laser driver wavefronts, parametrized by Zernike polynomials. We present optimization studies of laser plasma accelerators, towards beam energy control (more particles in a predetermined energy range), higher radiation production and shorter acceleration lengths. In each of these cases, we found the optimized beam to be significantly different from a regular Gaussian beam, even when optimizing the latter for focus and phase. The increase in the different optimization problems ranged from 10% in the acceleration minimization to 30% in radiation production.

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
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