Efficient modeling of laser-plasma accelerators using the ponderomotive-based code INF&RNO

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Laser plasma accelerators (LPAs) can produce accelerating gradients on the order of tens to hundreds of GV/m, making them attractive as compact particle accelerators for radiation production or as drivers for future high-energy colliders. [1, 2] In a laser plasma accelerator, a short and intense laser pulse propagating in an underdense plasma ponderomotively drives an electron plasma wave (or wakefield). The plasma wave has a relativistic phase velocity, and the charge separation between the plasma electrons and the neutralizing ions is responsible for the large accelerating and focusing fields.

Understanding and optimizing the performance of LPAs requires detailed numerical modeling of the nonlinear laser-plasma interaction. LPA simulations performed with conventional 3D electromagnetic Particle-In-Cell (PIC) codes are computationally very intensive, owing to the imbalance between the smallest and the largest spatial/temporal scale involved. Typically, the smallest scale in an LPA simulation is the laser wavelength (~micron), while the longest scale is the propagation distance (presently in the range of a few centimeters to a meter). For example, a cm-long LPA producing ~GeV electrons requires, in 3D, ~10^5 time steps, ~10^7 grid cells, and ~10^9 numerical particles with a computational cost of ~10^6 CPU-hours.

INF&RNO (INtegrated Fluid & paRticle simulatioN cOde) [3, 4] is an efficient 2D cylindrical code based on an envelope model for the laser, a PIC or fluid description for the plasma, and the averaged ponderomotive force approximation to describe the effect of the laser pulse on the plasma. These and other features, such as an improved laser envelope solver, and a quasi-static modality, allow for a speedup of several orders of magnitude compared to standard (explicit) full PIC simulations, while still retaining physical fidelity.

In this talk we report on the latest developments of the code, focusing in particular on the improved laser envelope solver, and we present simulation results concerning present (multi-GeV stages) and future (10 GeV stages) LPA experiments with the BELLA PW laser system at LBNL.

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[2] W. P Leemans et al., Phys. Rev. Lett 113, 245002 (2014)
[3] C. Benedetti et al., Proc. of AAC Workshop 1299 (2010) 250-255
[4] C. Benedetti et al., Proc. of ICAP (2012) THAAI2