Numerical Simulation of Laser-Accelerated Particle Beams and Their Applications

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Laser radiation shining on a plasma can excite very large electrostatic fields, resulting in the acceleration of copious amounts of energetic, multi-MeV particles from the target. Light particles (electrons) can be efficiently accelerated to ultra-relativistic energies by high-frequency electrostatic fields excited in the wake of a short laser pulse propagating in a low-density plasma. On the contrary, heavier particles (ions, mostly protons) are best accelerated by low-frequency fields, that can e.g. be produced at the surface of a solid-density target whose electrons have been heated by the laser.

The physical processes underlying these acceleration mechanisms will be reviewed, and we will discuss the requirements they impose on modeling.

Specific numerical codes are developed to study these phenomena. The multidimensional, relativistic Particle In Cell code CALDER is used to model laser – plasma interaction and collective particle acceleration. High-order weighting factors are key to reduce numerical heating in cases where high plasma densities and long times must be simulated. Alternatively, reduced model can come in handy for parameter studies, but at the expense of missing physics. In a second step, CALDER results can be coupled to Monte Carlo codes to compute particle transport through secondary targets and induced radiation (Bremsstrahlung and/or activation), target heating or beam deflection.

We apply these codes to the study of electron wakefield acceleration [1,2,3] and ion acceleration off laser-irradiated solid targets [4,5]. We will review some applications of these particle sources to physics and medicine, and pending developments in experiments and modeling.

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