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Nicholas Metropolis Award Talk: Quasi-static Modeling of Plasma and Laser Wakefield Acceleration[1]

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Plasma wakefields driven by intense ultrashort charged particle or laser beams can sustain acceleration gradients three orders of magnitude larger than conventional RF accelerators. These wakefields are promising for accelerating charged particles in short distances for applications such as an energy booster of a linear collider and as a ultra-compact accelerator. In the Plasma Wakefield Accelerator (PWFA) or Laser Wakefield Accelerator (LWFA), the space charge force of an electron beam or the ponderomotive force of a laser beam expels plasma electrons away from its path, forming a bubble-like structure where the longitudinal electric field inside of it provides accelerating and the transverse Lorentz force provides focusing forces on electrons. Recently, quasi-monoenergetic beams from self-trapped plasma electrons in wakefields driven by intense laser beamd have been observed in experiments in many laboratories around the world, and a PWFA experiment performed at Stanford Linear Accelerator Center (SLAC) successfully demonstrated that the energy of particles at the tail of the driving electron can be doubled from ∼40 GeV to ∼80 GeV in just 80 cms. However, to fully understand these experiments requires a particle-based computer model because the interaction between the plasma and the driver is highly nonlinear. We have developed a highly efficient, fully parallelized, fully relativistic, three dimensional particle-in-cell code, QuickPIC, for simulating plasma wakefield acceleration. The model is based on what is called the quasi-static or frozen field approximation, which assumes that the driver does not evolve during the time it takes for it to pass a plasma particle and reduces a fully three-dimensional electromagnetic field calculation and particle push into a two-dimensional electrostatic field solve and particle push. This algorithm reduces the computational time by at least 2 to 3 orders of magnitude. Comparison with a fully explicit PIC model (OSIRIS) shows excellent agreement for problems of interest. QuickPIC simulations of the SLAC PWFA experiment have revealed important physics and achieved good agreement with experiment measurement. Theoretical analysis of the stability of acceleration can now be guided and verified by QuickPIC simulations.

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