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Ab Initio Petaflop-scale Particle-in-Cell Simulation of Laser-Plasma Interaction[1]

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Large three-dimensional (3D) particle-in-cell (PIC) simulations have been performed using the VPIC code on some of the world's largest supercomputers, including the Roadrunner supercomputer, the first machine capable of a petaflop/s. These simulations have revealed the complex physical mechanisms underlying laser-plasma interactions and show an emerging universal picture of nonlinear saturation of LPI in the kinetic regime. Moreover, with the advent of peta-scale computing, we are entering an era of "at-scale" modeling necessary to understand the essential nonlinearity of LPI in solitary laser speckles, the building-blocks of multi-speckle beams. Under NIF-relevant conditions, stimulated Raman scattering (SRS) vs. speckle intensity shows a sharp onset at a threshold intensity (below linear estimates) and saturation at higher intensity, as validated in Trident experiments. Wavefront bowing of electron plasma waves (EPW) from trapped electron nonlinear frequency shift and amplitude-dependent damping is observed in 3D. This is followed by trapped particle modulational instability, which evolves nonlinearly into self-focusing, rapid transverse EPW phase variation, increased loss of trapped electrons, and EPW damping. In 3D, EPW turbulence may also exhibit loss of coherence through azimuthal filamentation. This reduction of source coherence for backscattered light and increased damping limit how much backscatter can obtain in a speckle. In addition, 3D modeling of novel ultraintense laser-ion acceleration mechanisms will be shown. Collaborators: L. Yin, K. J. Bowers, B. Bergen, D. S. Montgomery, J. L. Kline, H. A. Rose, B. M. Hegelich, K. A. Flippo, J. C. Fernández.

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