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Title: iVPIC: A low---dispersion, energy---conserving relativistic PIC solver for LPI simulations

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iVPIC: A low-dispersion, energy-conserving relativistic PIC solver for LPI simulations[1]

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We have developed a novel low-dispersion, exactly energy-conserving PIC algorithm for the relativistic Vlasov-Maxwell system. The approach features an exact energy conservation theorem while preserving the favorable performance and numerical dispersion properties of explicit PIC. The new algorithm has the potential to enable much longer laser-plasma-interaction (LPI) simulations than are currently possible.

Explicit relativistic PIC algorithms are the workhorses for LPI physics exploration. They are well suited for the problem at hand, as LPI demands resolution of the fastest time scales and the smallest length scales for physical fidelity. Moreover, explicit PIC can be tuned to provide very low numerical dispersion of the light wave, which is critical for numerical accuracy of LPI. And finally, the simple computational kernels of the explicit particle push can be highly optimized in modern architectures, resulting in breathtaking performance (currently VPIC spends only a few nanoseconds per particle push in KNL architectures).

However, explicit PIC algorithms are unsuitable for very long timescale simulations, owing to intolerable accumulation of energy conservation errors. For these applications, there is a need for discretely energy-conserving relativistic Vlasov-Maxwell PIC algorithms. Implicit PIC methods can enforce discrete energy conservation, but lack the required numerical dispersion properties for accuracy in the LPI context.

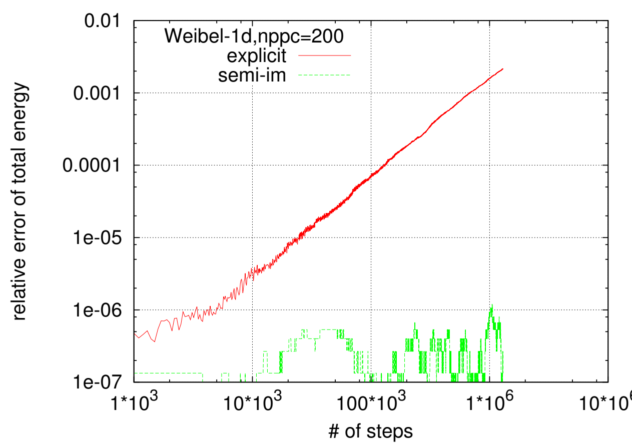

Figure 1. Energy conservation histories for explicit PIC (red) and the new energy-conserving algorithm (green).

We have formulated (and implemented in the VPIC code) a low-dispersion, discretely energy-conserving algorithm (EC-PIC) by combining the strongest numerical elements of implicit and explicit PIC algorithms without severely impacting performance. The EC-PIC scheme features an exact discrete energy conservation theorem while providing comparable numerical dispersion properties to explicit PIC. Figure 1 depicts energy conservation time histories for both explicit PIC and EC-PIC for a 1D Weibel instability run for 10^7 timesteps. It demonstrates EC-PIC conserves energy to numerical round-off (single-precision), while explicit PIC features secular energy error growth. The approach is currently being evaluated in a 2D LPI application.

[1] G. Chen et al, "A low-dispersion, energy conserving relativistic electromagnetic PIC algorithm," in preparation. A copy of this manuscript will be provided when ready.