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High-Performance Computing using GPU for plasma acceleration

Plasma accelerators enable the acceleration of charged particles over short distances due to their multi-GeV/m field gradients, making them a compact alternative to conventional technologies. Despite large progress on beam energy and quality over the last decade, significant progress is still required on beam quality and stability to fill the gap between promising concepts and production-ready accelerators. The Particle-in-Cell (PIC) method is a reliable tool to simulate plasma acceleration, and PIC simulations play a major role in understanding, exploring and improving plasma accelerators.

In the PIC method, the electric and magnetic fields are resolved on a grid, and the plasma dynamics is represented by an ensemble of macro-particle moving freely in the domain, and constantly interacting with the grid. Production simulations routinely use billions of grid cells and macro-particles, making the use of high-performance computing a necessity. In this presentation, we will discuss progress on numerical schemes, algorithms and hardware to enable high-fidelity simulations in a reasonable time in a rapidly-evolving landscape. The new open-source, GPU-capable quasi-static PIC code HiPACE++ will be presented. Built on the open-source mesh refinement library and portability layer AMReX, the code demonstrates considerable acceleration over comparable implementations, and excellent scaling up to hundreds of GPUs.

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