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Beyond Dephasing: Scalable laser-plasma accelerators via Traveling-wave electron acceleration

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Traveling-wave electron acceleration (TWEAC) is a next-generation laser-plasma acceleration scheme that bypasses dephasing, pump depletion and diffraction limitations, offering a clear path toward compact accelerators beyond 10 GeV, making it a candidate for future compact accelerators based on existing CPA lasers. TWEAC utilizes two pulse-front tilted laser pulses whose propagation directions enclose a configurable angle. The accelerating cavity is created along their overlap region in the plasma and can move at the vacuum speed of light. The oblique laser geometry enables to constantly cycle different laser beam sections through the interaction region, hence providing quasi-stationary conditions of the wakefield driver. This approach decouples the need for staging from plasma physics, making the design of multiple stages rather a choice that follows the capabilities of the laser systems used.

We present recent results based on large scale 3D simulations conducted at OLCF's Frontier cluster using PIConGPU. For reaching linear, high-gradient cavities at high laser to electron beam energy efficiency we investigate TWEAC regimes featuring small-incident angle focal geometries in the range of 5 - 10°. In addition, we discuss current progress and challenges of maintaining steady-state accelerating conditions to high-energies.

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