Contribution ID: **169** Type: **Contributed Oral**

Traveling-wave electron accelerators – towards scalable laser-plasma accelerators beyond 10GeV

Monday, 7 November 2022 13:50 (30 minutes)

Traveling-wave electron acceleration (TWEAC) is an advanced laser-plasma accelerator scheme, which is neither limited by dephasing, nor by pump depletion or diffraction. Such accelerators are scalable to energies beyond 10 GeV without the need for staging and are candidates for future compact electron-positron colliders 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.

The TWEAC geometry enables to access to a wide range of regimes, which are customizable in cavity geometry, laser-to-electron energy efficiency and the required laser properties at different plasma densities, making the scheme suitable for high-rep rate lasers at low energies per pulse to multi-PW laser facilities. Exploring these regimes in high-fidelity simulations is computationally highly demanding, as these need to include large plasma volumes in 3D at high-resolution over an extended acceleration distance. Since even "small" test simulations need hundreds of GPUs, TWEAC simulations require exascale compute resources.

We present recent progress in TWEAC simulations and various technical advances in the 3D3V particle-in-cell code PIConGPU that enable running on the upcoming Frontier cluster, most notably support of the HIP computational backend allowing to run on AMD GPUs, as well as openPMD, PICMI and algorithmic developments. These advances are mainly driven by our participation in OLCF's Frontier Center for Accelerated Application Readiness providing access to the hardware platform of the Frontier exascale supercomputer. We show performance data and recent applications of PIConGPU profiting from these developments.

Acknowledgments

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Session Classification: WG2: Computation for Accelerator Physics

Track Classification: Working Group Parallel Sessions: WG2 Oral: Computation for Accelerator Physics