Modeling chromatic emittance growth in staged plasma wakefield acceleration to 1 TeV using nonlinear transfer matrices

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A framework for integrating transfer matrices with particle-in-cell simulations is developed for TeV staging of plasma wakefield accelerators [1]. Using nonlinear transfer matrices in terms up to ninth order in normalized energy spread $\sqrt{\langle\delta\gamma^2\rangle}$ and deriving a compact expression for the chromatic emittance growth in terms of the nonlinear matrix, plasma wakefield accelerating stages simulated using the three-dimensional particle-in-cell framework OSIRIS 4.0 were combined to model acceleration of an electron beam from 10 GeV to 1 TeV in 85 plasma stages of meter scale-length with long density ramps and connected by simple focusing lenses. In this calculation, we find that for initial relative energy spreads below 10^{-3}, energy-spread growth below 10^{-5} of the energy gain per stage and normalized emittance below mm-mrad, the chromatic emittance growth can be minimal. The technique developed here may be useful for plasma collider design, and potentially could be expanded to encompass non-linear wake structures and include other degrees of freedom such as lepton spin.

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References

[1] Alec G. R. Thomas and Daniel Seipt, Phys. Rev. Accel. Beams 24, 10, 104602 (2021).