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# Optimization of transformer ratio and beam loading in plasma wakefield accelerator with a structure-exploiting algorithm

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Plasma-based acceleration has emerged as a promising candidate as an accelerator technology for a future linear collider or a next-generation light source. We consider the plasma wakefield accelerator (PWFA) concept where a plasma wave wake is excited by a particle beam and a trailing beam surfs on the wake. For a linear collider, the energy transfer from the drive beam to the wake and from the wake to the trailing beam must be large, while the emittance and energy spread of the trailing bunch must be preserved. One way to simultaneously achieve this for accelerating electrons is to use longitudinally shaped bunches and nonlinear wakes. In the linear regime, there is an analytical formalism to obtain the optimal shapes. In the nonlinear regime, however, the optimum shape of the driver to maximize the energy transfer efficiency cannot be precisely obtained as there is at present no theory that describes the wake structure and excitation process for all degrees of nonlinearity, and because the plasma electron response at the beginning of the drive beam transitions from a linear to a nonlinear behavior. We present results using a novel optimization method to effectively determine a current profile for the drive and trailing beam in PWFA that provides low energy spread, low emittance, and high acceleration efficiency. We parameterize the longitudinal beam current profile as a piecewise linear function and define optimization objectives. For the trailing beam the algorithm converges quickly to a nearly inverse trapezoidal trailing beam current profile similar to that predicted by the ultra-relativistic limit of the nonlinear wakefield theory. For the drive beam, the algorithm-searched optimal beam profile in the nonlinear regime that maximizes the transformer ratio also resembles that predicted by linear theory. The current profiles found from the optimization method provide a higher transformer ratio compared with the linear ramp predicted by the relativistic limit of the nonlinear theory. We will present details of the optimization procedure and results on obtaining high energy transfer efficiency in a PWFA two bunch accelerator stage.

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