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A preliminary analysis for efficient laser wakefield acceleration

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Adopting a recently developed simplified model of the impact of a very short and intense laser pulse onto an inhomogeneous diluted plasma, we analitycally derive preliminary conditions on the input data (initial plasma density $\widetilde{n_0}$ and pulse profile) allowing to control the wave-breaking of the laser-driven plasma wakefield and to maximize the energy transfer to small bunches of self-injected electrons. The model is a fully relativistic plane hydrodynamic one: The pulse is a plane wave propagating in the z-direction hitting a cold plasma at rest with $\widetilde{n_0} = \widetilde{n_0}(z)$; as long as the depletion of the laser pulse is small the system of the Lorentz-Maxwell and continuity PDEs is reduced to a family (parametrized by $Z > 0$) of decoupled systems of non-autonomous Hamilton equations with 1 degree of freedom 1 and the light-like coordinate $\xi = ct{-}z$ (instead of time t) as an independent variable; each Z is the initial z-coordinate of a layer of electrons, whose motion is ruled by the corresponding system. Wave-breaking (and self-injection) start when the Jacobian $J = \partial z/\partial Z$ vanishes. In the more realistic situation of a finite, but not too small, laser spot radius R, the results will approximately hold for the part of the plasma close to the axis $\vec{z}$ of cylindrical symmetry of the spot, and may be used to preselect interesting regions in the input parameter space where to perform, by PIC simulations, more accurate analysis of the wakefield acceleration.

Acknowledgments

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