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On an analytical optimization of plasma density profiles for downramp injection in laser wake field acceleration

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Given a very short and intense plane-wave laser pulse travelling in the positive z direction, we propose a multi-step preliminary analytical procedure to tailor the initial density profile $\widetilde{n_0}(z)$ of a cold diluted collisionless plasma to the pulse, so as to control the formation of the plasma wave (PW), its wave-breaking (WB) at density inhomogeneities, the self-injection of low-charge bunches of plasma electrons in the PW by the first WB at the density down-ramp, and to maximize the initial stages of the laser wakefield acceleration of the latter. The procedure consists in partially *inverting* our resolution procedure of the following *direct* problem: given $\widetilde{n_0}(z)$ and laser pulse, determine the motion of the plasma electrons. Such a resolution is based on a "post-hydrodynamic" (i.e. multi-stream) fully relativistic plane model, which is valid as long as the pulse depletion can be negleted. Up to WB, we are able to reduce the Lorentz-Maxwell and electrons' fluid continuity equations to a family (parametrized by $Z>0$) of *decoupled pairs* of Hamilton equations for a 1-dimensional system. Here, Z pinpoints the infinitesimal layer of electrons having coordinate $z=Z$ for $t\le 0$, $\xi=ct-z$ replaces time t as the independent variable. To make the inversion formulae maneagable, we stick to slowly varying density profiles $\widetilde{n_0}(z)$. We check the effectiveness of the $\widetilde{n_0}$ resulting from the inversion formulae, and can then further improve it by fine-tuning, solving again the direct problem (first the equations of our plane model, then those obtained with Particle In Cell codes).

Working group

WG1 : Laser-driven plasma wakefield acceleration

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