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Physics of transverse dynamics in a laser-plasma accelerator

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Laser Wakefield Accelerators (LWFA) offer a promising solution for producing high-energy electron beams in compact setups. Beyond obtaining the required energy, the beam quality (emittance, energy spread, intensity) must also be optimized for LWFA to be considered an alternative to conventional accelerators. Achieving precise control of the transverse beam dynamics is one of the key challenges. This article thoroughly studies the physics governing the evolution of emittance and Twiss parameters within the plasma stage, on the density plateau, and in the up-ramp and down-ramp connections to conventional transport lines. Analytical and numerical analysis will be conducted using a toy model made of special quadrupoles, allowing numerical calculations to be sped up to a few seconds/minutes. Matching between plasma and transport lines will be extensively studied, clearly showing the dependence on initial conditions, and recommendations for the best realistic configurations will be provided.

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