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Machine learning-based optimisation of plasma density ramps at CLARA FEBE

Plasma wakefield acceleration (PWFA) offers acceleration gradients much larger than that in conventional accelerators. The Full Energy Beam Exploitation (FEBE), a new beamline attached to the Compact Linear Accelerator for Research and Applications (CLARA) at Daresbury Laboratory, has been designed as a dedicated test facility for users. By providing access to high-power lasers and electron beams, FEBE enables the validation of proof-of-principle experiments for innovative applications. In this work, we numerically investigate PWFA with a two-bunch configuration, i.e., the driver/witness bunch generated at CLARA FEBE, to enhance the beam quality of the accelerated witness bunch. Machine learning-based optimisation of the plasma density ramp, involving ramp position, peak density, and ramp sharpness, has been performed. Additional simulations validate and assess the trained model. Meanwhile, tolerance and sensitivity analyses are carried out to evaluate robustness and inform future proof-of-principle experiments.

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