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Stability of the Plasma-Modulated Plasma Accelerator (P-MoPA)

Wednesday, 20 September 2023 19:00 (1h 30m)

We investigate the operation regime and performance of the Plasma-Modulated Plasma Accelerator (P-MoPA), a new approach offering the potential for high-repetition-rate, GeV-scale laser plasma accelerators (LPA) driven by picosecond-duration laser pulses [Phys. Rev. Lett. 127, 184801 (2021)]. P-MoPA uses a plasma modulator stage, which introduces a spectral modulation to a picosecond pulse from a Yb:YAG thin-disk laser. This forms a frequency comb, allowing for compression into a train of femtosecond-class pulses, promising a drive for a kHz rep-rate, GeV-scale LPA. We derive a 3D analytic theory of the plasma modulator for the pulse and wakefield evolution in long pre-formed plasma channels, identifying a transverse mode instability (TMI) that can limit the energy of the drive pulse [Phys. Rev. E 108, 015204 (2023)]. We find the theory agrees with PIC simulations, showing that TMI is the limiting factor of the plasma modulator and allows multi-joule drive pulses corresponding with multi-GeV electron beams. Optimization of LPAs driven by P-MoPA pulse trains showcases the key differences between the pulse trains formed by P-MoPA and the traditional beat-wave method, emphasizing P-MoPA's unique feature of longitudinal shaping control. This study contributes to advancements in overcoming the repetition rates and energy efficiency limitations of traditional LPAs.

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