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Multi-Joule Scalable, Distortion-Free Pre-Pulse Contrast Enhancement Using Multi-pass Cells

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It is well known that high (105 to over 1010) temporal laser pulse contrasts are necessary to mitigate undesirable prepulse effects in laser-plasma acceleration (LPA) and other high-field applications. Many pulse contrast enhancement schemes have been devised to meet this requirement, but tend to suffer from low efficiency, inadequate prepulse suppression, beam distortion, or a combination thereof. Furthermore, developing a design that may tolerate Joule-class energies at high repetition rates (multi-kW average powers) as envisioned for the next-generation LPA drivers has been a challenge.

We present a compact multi-pass cell (MPC) pulse cleaning scheme that is scalable to high repetition rates and multi-Joule energies while maintaining beam quality, designed for the flat-top nanosecond pulses of a coherently combined fiber laser system after temporal combining but before compression. This approach leverages nonlinear effects to strongly attenuate low-power prepulses while transmitting the high-power main pulse with low loss. Considering only cleaning losses, simulation indicates that for 1.8 J pulses a 2.52m cavity may provide 100 dB (1010) of prepulse suppression at 90% main pulse power transmission and negligibly low (< 0.8π radians) B-Integral. In the near term, we are pursuing an experimental demonstration with low energies as a proof of concept. Simulation of this design with 10 mJ pulses indicates that a cm-scale cavity can provide over 60 dB (106) of prepulse suppression at 91% main pulse transmission and low B-Integral (< π radians). Experimental validation of this result is in progress.

Working group

WG1 : Laser-driven plasma wakefield acceleration

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