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Stabilization and manipulation of laser-driven plasma acceleration with a weak auxiliary laser pulse

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We show that uncontrolled phase fluctuations within an outer annulus of the near-field profile of a laser-wakefield drive pulse are primarily responsible for shot-to-shot fluctuations in the energy, charge, and pointing of wakefield-accelerated electrons. When a mask removes this unstable annulus, RMS fluctuations decrease by more than half without compromising average electron energy substantially. When light from the removed annulus is re-shaped into a co-polarized pulse that peaks on axis and co-propagates at controlled delays -120 < Δt < 120 fs with respect to the 10× more intense drive pulse, fluctuations in electron and betatron x-ray properties reappear, peaking in amplitude when the weak pulse overlaps either the drive pulse (Δt = 0) or accelerating electrons and the tail of the drive pulse (Δt ≈ 30 fs). In the latter case, a net increase in average electron energy is observed. The results suggest the possibility of precisely and widely tuning the properties of laser-wakefield-accelerated electrons using a comparatively weak auxiliary pulse with a stable, independently controlled carrier envelope phase.

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