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Plasma electron acceleration driven by a long-wave-infrared laser

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We report self-injecting LWFA driven by CPA-CO2 laser pulses of wavelength ~10 micrometers at Brookhaven's Accelerator Test Facility [1]. Long-wave IR pulses open opportunities to drive large wakes in low-density plasma more efficiently than near-IR pulses, potentially enabling higher-quality accelerated bunches. In experiments, 0.5-TW, 4-ps laser pulses generated no electrons, but drove self-modulated wakes characterized by optical scattering in plasma of density down to 4e17 cm-3, when peak power exceeded the critical power for relativistic self-focusing. 2-ps pulses with power up to 5-TW captured and accelerated electrons to relativistic energy in plasma of density as low as 3e16 cm-3. The shortest, most powerful pulses generated up to 0.4 nC total charge, including a collimated quasi-monoenergetic peak at ~10-MeV, along with a low-energy background. This marked the onset of a transition from self-modulated to the bubble regime. 3D Particle-in-cell simulations accurately predicted the thresholds for wake excitation and for self-injection, and other key details. The results portend future accelerators in which yet shorter, more powerful CO2 pulses drive plasma bubbles of ~300-micron radius, that can preserve the low emittance and energy spread of electron bunches injected externally from a synchronized low-energy linac.

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