CO2-laser-driven wakefield acceleration

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The evolution of Laser Wakefield Accelerators (LWFAs), from initial concept [1] to the current multi-GeV electron sources [2], has relied on solid state lasers operating in a very narrow range of near infrared wavelengths ($\lambda \sim 0.8$ µm to ~1 µm), since only such lasers have been able to produce sufficiently powerful, ultrashort pulses. Multi-terawatt, ~1 ps laser pulses, in the long wavelength infrared (LWIR) range of $\lambda \sim 9$ to 11 µm, are now emerging from high-pressure, mixed-isotope CO_2, chirped-pulse-amplified laser technology [3]. Such LWIR pulses open the opportunity for more efficient generation of large accelerating structures (λ_p up to hundreds of *µm at* densities $n_e < 10^{17}$ cm^{-3}) that would enable precise injection and subsequent preservation of energy spread and emittance of accelerated electrons.

At the previous LPAW, we reported the detection and space and time characterization of plasma waves generated in the self-modulated regime by sub-terawatt CO_2 laser pulses, in plasma density as low as 5 10^{17} cm^{-3}. No accelerated charge was detected under those conditions. Here we report new results, in which copious relativistic electrons emerge from high-amplitude, self-modulated wakes driven by up to 4TW, 2ps CO_2 laser pulses, in low-density plasma (10^{16} cm^{-3} < n_e <10^{18} cm^{-3}). Measurements and simulations of wake structure and e-beam properties as conditions change detail the physics of long-wavelength-infrared self-modulated wakefield acceleration. Peaked electron spectra observed on many shots indicate that we are close to generating strongly nonlinear wakes, portending future higher-quality accelerators driven in the bubble regime [4] by yet shorter (0.5 ps), more powerful ($\gtrsim$ 20 TW) CO_2 laser pulses [5]. Experiments have been conducted at Brookhaven National Laboratory's Accelerator Test Facility.

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