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# CO2-laser-driven wakefield acceleration

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To date only solid-state laser pulses of wavelength ⊠ ~ 1 micron have been powerful enough to drive laser wakefield accelerators (LWFAs). Chirped-pulse-amplified multi-terawatt, ~1 ps laser pulses of ⊠ ~ 10 µm are now emerging from mixed-isotope, high-pressure $CO_2$ laser technology [1]. Such pulses open new opportunities to drive large ($R_b \sim 300$ µm) bubbles in low-density ($n_e < 10^{17}$ cm$^{-3}$) plasma more efficiently, and to preserve energy spread and emittance of accelerated electrons better, than is possible using conventional ~1 µm drive pulses [2]. At the previous AAC we reported observations of wakes driven by sub-terawatt (sub-TW) $CO_2$ laser pulses in plasma of density down to $5 \times 10^{17}$ cm$^{-3}$ via collective Thomson scatter of a probe pulse. However, no electrons were accelerated in those experiments. Here we report new experiments in which copious relativistic electrons emerge from high-amplitude, self-modulated wakes driven in plasma of density down to $n_e < 10^{17}$ cm$^{-3}$ driven by 5- to 10-TW, 2 ps $CO_2$ laser pulses. 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 [2] by yet shorter (0.5 ps), more powerful (⊠ 20 TW) $CO_2$ laser pulses [3]. Experiments are carried out at Brookhaven National Laboratory's Accelerator Test Facility.

[1] M. N. Polyanskyi, I. V. Pogorelsky, M. Babzien, and M. A. Palmer, OSA Continuum 3, 459-472 (2020).
[2] P. Kumar, K. Yu, R. Zgadzaj, M. C. Downer, I. Petrushina, R. Samulyak, V. N. Litvinenko and N. Vafaei-Najafabadi, Phys. Plasmas 28, 013102 (2021).
[3] M. N. Polyanskyi, I. V. Pogorelsky, M. Babzien, R. Kupfer, K. L. Vodpyanov, and M. A. Palmer, Opt. Express 29, 31714 (2021).

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