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Demonstration of a beam loaded nanocoulomb-class laser wakefield accelerator

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Laser-plasma wakefield acceleration is capable of producing quasi-monoenergetic electron beams reaching into the GeV range with few-femtoseconds bunch duration. Scaling the charge to the nanocoulomb range would yield hundreds of kiloamperes peak-current and stimulate the next generation of radiation sources covering high-field THz, high-brightness X-ray and γ-ray sources, compact FELs and laboratory-size beam-driven plasma accelerators. Laser-plasma accelerators generating such high currents operate in the beam loading regime where the accelerating field is strongly modified by the self-fields of the injected bunch, improving the final beam quality if appropriately controlled. Here we experimentally investigate the effects of beam loading at the theoretically predicted limit by loading unprecedented charges of about 0.5 nC within a mono-energetic peak into the first plasma cavity. As the energy balance is reached, the final energy spread is minimized. We show that the beam quality is maintained up to an estimated peak-current of 50 kA, an order of magnitude larger than in state-of-the-art conventional and laser-plasma accelerators.

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