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Experimental generation of petawatt peak power electron beams via laser heater shaping at FACET-II

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We report on the experimental generation of high-energy (10 GeV), ultra-short (fs-duration), ultra-high current (0.1 MA) electron beams with petawatt peak power at FACET-II [1]. These extreme beams enable the exploration of a new frontier of high-intensity beam-light and beam-matter interactions broadly relevant across fields ranging from advanced accelerators, laboratory astrophysics, strong field quantum electrodynamics and ultrafast quantum chemistry. We demonstrate our ability to generate and control the properties of these electron beams using a laser heater, which exploits the coherent interaction between a laser pulse and an electron beam in a magnetic undulator to shape the electron beam distribution. By tailoring the laser heater's temporal profile, we can modulate the beam's current profile on-demand, creating designer electron beams for specific applications. We characterize the charge, peak current, and duration of these beams and show their use in initiating beam-induced ionization of gas targets relevant to advanced accelerator applications. The extreme beams generated in this work have already found applications in the FACET- II experimental program for studying plasma-based injection schemes and the transition between the nonlinear and wakeless regimes in beam-driven plasma wakefields.

[1] C. Emma et al., PRL 134, 085001 (2025)

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