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Online Correction Of Laser Focal Position Via Deployable Machine Learning Models

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Ultrafast lasers play an increasingly critical role in the generation, manipulation, and acceleration of electron beams. Laser plasma accelerators enable order of magnitude improvements in accelerating gradient and promise compact tunable GeV electron beam sources, while novel photocathode systems permit fundamental advances in electron beam manipulation for accelerator and radiation applications. Advances in fast feedback systems are required to stabilize laser performance at kHz repetition rate operation against environmental fluctuations. A field programmable gate array (FPGA) based digital control system, coupled with responsive optics, can provide rapid and precise stabilization of ultrafast lasers. Here we report on an effort to develop, test, and deploy these systems across a range of beamlines operating at >1 Hz repetition rate, including 1 kHz systems. Our initial efforts demonstrate the calibration of a fast, non-destructive focal position diagnostic in concert with a deployable correction scheme. The resulting prototype shows diagnostic responsiveness into the 100s of Hz.

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