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High-bandwidth image-based predictive laser stabilization via optimized Fourier filters

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Producing stable particle beams with Laser Plasma Accelerators depends upon the stability of the driving laser (for example, in pointing). Vibrations from various sources (HVAC systems, chillers, motorized stages, among others) introduce laser pointing fluctuations which couple to the particle beam production, and degrade shot-to-shot stability. Luckily, active stabilization is an option, even on low-repetition rate systems due to the co-presence of CW alignment means and un-amplified kHz front-end beams. However, traditional PID systems are strongly limited in feedback bandwidth. Here we present a predictive, machine-learning control approach which drastically improves control bandwidth compared to traditional algorithms. By computing Fourier transform coefficients in real-time, along with efficient data pipelining and CMOS camera technology, vibration disturbances in laser pointing up to 500 Hz have been shown to be greatly reduced.

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