Sub-100µs latency feedback control of laser machining using FPGA-powered inline coherent imaging

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Abstract

Accurate real-time measurement of laser penetration depth for feedback control is desirable for a variety of laser material processing applications in both micro- and macro-processing fields. Inline coherent imaging (ICI), a recently-developed interferometric technique, provides this capability with micron-scale precision whereby images can be captured at rates up to 312 kHz[1]. However, ICI image analysis is computationally intensive, and its usefulness in high-speed feedback control is limited by the >1ms latency that is introduced by PC architecture. To address this issue, we have implemented ICI analysis for real-time applications on a dedicated Field-Programmable Gate Array (FPGA). FPGAs consist of configurable digital logic that offers superior parallel processing capabilities with exceptionally deterministic performance. Using this FPGA technology, we have managed to reduce the latency of a complete depth measurement cycle (including both acquisition and analysis) to 54±5 µs, more than an order of magnitude improvement over traditional processing methods.

We will present the FPGA ICI system's performance as a sensor for an autofocus feedback loop, wherein the ICI depth signal is used to control the height of a mechanical motion stage to maintain machining beam focus at the surface of samples with variable morphology. The response time of this system (41 ms) is dominated by the motion of the stage and not by the latency of the feedback signal. Since industrial kW-class laser powers can be modulated at much faster rates, active control of laser welding depth fully exploits the low-latency of our FPGA imaging system. We will also present the results of this preliminary FPGA-based welding control.