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Controlled laser processing: from kW continuous-wave to ultrafast

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Laser materials processing can differ by orders of magnitude in terms of both the light-matter interaction times and the spatial dimensions of the interaction regions. This multiplicity has stymied efforts to develop a universal tool for on-line laser process monitoring and control. Previously, we developed a diagnostic called inline coherent imaging (ICI) for real-time, in-situ measurements of laser-induced sample morphology changes [1]. ICI is similar to optical coherence tomography (a medical imaging technique), and provides micron-scale axial resolution. Now with a dynamic range exceeding 60 dB and line rates above 300 kHz, we show that ICI allows us to monitor and study the volcanic stochasticity of kW-class laser welding, and to control this highly dynamic process on the fly. More recently, we have implemented fully automatic laser micro-milling with an ICI-enabled feedback system, reproducing complicated 3D shapes in heterogeneous materials as distinct as wood and bovine cortical bone. In effect, we have a non-contact CNC capable of replicating features down to micron resolution in arbitrary materials. ICI provides highly adaptable process control as well as a window into previously concealed dynamics at the tip of a high-power laser beam.

[1]. Webster, P.J.L. *et al.* In situ 24 kHz coherent imaging of morphology change in laser percussion drilling. Opt. Lett. **35**, 646-648 (2010).

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