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At the tip of an intense laser beam: operando monitoring of laser processing in manufacturing

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A kW laser beam focused on metal creates a highly dynamic environment of considerable importance to automotive production and 3D additive manufacturing. For example, laser welding allows the use of non-traditional materials to reduce vehicle weight (for improved fuel efficiency) but provides no direct on-the-fly quality indicator. The dramatic increase in demand for electric vehicles has required the development of completely new manufacturing techniques (*e.g.*, welding 100s of battery tabs) necessitating the development of new monitoring techniques to ensure compliance with stringent part quality requirements. Metal 3D printing promises custom part creation at the push of a button, but slow print speeds coupled with inconsistent part quality and expensive *ex situ* quality assurance (*e.g.*, x-ray CT) have slowed widescale adoption. We developed inline coherent imaging, an interferometric imaging approach easily deployable in the field that can monitor laser processing *operando* at high speeds (>300 kHz) and high resolutions (< 10 micron) [1]. Recent work combines this approach with other *in situ* diagnostics (*e.g.*, integrating sphere radiometry) to capture simultaneous depth and absorptance to reveal the microscopic origin of the highly efficient energy coupling from light to metal integral to laser welding [2]. Simultaneous capture of morphology through both inline coherent imaging and high-speed x-ray imaging (possible only with synchrotron-based light sources) definitively explains the supposed "noise"in optical depth imaging [in preparation]. In metal 3D printing, we track morphology layer by layer, providing an immediate check on surface roughness, recoater blade damage, and powder packing density [3]. Defects are corrected through closed-loop control before subsequent layer deposition.

[1] Webster *et al.*, Optics Letters 39, 6217-6220 (2014).
[2] Allen *et al.*, Procedia CIRP 111, 5-9 (2022).
[3] Fleming *et al.*, Additive Manufacturing 32, 100978 (2020).

Keyword-1

laser process monitoring

Keyword-2

interferometic imaging

Keyword-3

quality assurance

Author: Prof. FRASER, James

Co-authors: ALLEN, Troy R; FLEMING, Tristan G

Presenter: Prof. FRASER, James

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