BEAM SHAPING IN ADDITIVE MANUFACTURING: MODELLING, SIMULATION AND PROCESS DESIGN

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ABSTRACT

Beam shaping is rapidly emerging as one of the promising innovations in laser-based additive manufacturing (AM). Modern optical systems can generate highly customized beam profiles, enabling unprecedented control over energy deposition, melt-pool dynamics, and solidification behavior. Experimental studies have demonstrated wider process windows, increased process speed, reduced defect formation, and new opportunities for microstructure and texture control. The increasing availability of beam-shaping technologies, including diffractive and refractive optics, multi-core fibers, coherent beam combining, spatial light modulators, and high-frequency beam oscillation, has created a vast process design space. Exploring this space experimentally alone is neither practical nor economically feasible. Predictive modeling and simulation, therefore, play a crucial role in identifying promising beam profiles, understanding the governing physics, and accelerating industrial implementation.

This Invited Session aims to bring together researchers working on experiments, in-situ characterization, and simulation of beam shaping in AM. Particular emphasis will be placed on connecting modeling and simulation with experimental observations, validating simulations through advanced diagnostics, and discussing pathways towards robust AM. Ultimately, the session seeks to advance the understanding of how tailored laser energy distributions can be systematically designed, optimized, and qualified for next-generation AM. Topics of interest include, but are not limited to:

- Beam shaping for laser-based powder bed fusion and directed energy deposition
- High-fidelity multiphysics modeling of melt-pool dynamics, vapor depression formation, and keyhole behavior under non-Gaussian beam profiles
- Solidification, microstructure, and texture control through tailored energy input
- Inverse design and optimization of beam profiles and scan strategies
- In-situ monitoring, high-speed imaging, and synchrotron X-ray imaging for model validation

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