**Max Gero Zimmermann**
Fraunhofer-Institut für Lasertechnik ILT, Aachen, Germany

# Digitization of brownfield laser coating systems: A modular retrofit for inline quality assurance and unsupervised anomaly detection

Plasma/laser-assisted deposition techniques

**Abstract**
Extreme High-Speed Laser Material Deposition (EHLA) enables metallic coatings with variable thickness at deposition speeds of several hundred meters per minute and deposition rates of several kilograms per hour. Compared to conventional build-up welding processes, EHLA reduces heat input and increases precision, making it particularly attractive for materials that are difficult to weld and for component repair. However, the highly nonlinear interactions between laser power, powder feed rate, focus position/stand-off distance, scanning speed, and shielding gas management make robust parameterization and control difficult. Even after process development is complete, errors or anomalies can still occur in series production that cannot be reliably detected by existing monitoring systems. If such deviations are detected too late, unnecessary costs arise in subsequent production steps or the component may fail during operation. Although EHLA is a relatively young process (≈15 years), many applications run on brownfield machines, where heterogeneous controls, limited interfaces, and a lack of data continuity hinder effective quality assurance.

We present a modular, scalable retrofit framework that digitizes brownfield machines without compromising safety-critical functions and enables both statistical and AI-based quality assurance. The concept combines non-invasive sensor technology (e.g., dual camera, pyrometer) with a real-time interface for deterministic time synchronization and can be integrated into IT systems via standardized protocols. Process and quality data are referenced along the tool path in a uniform data model and consolidated into a digital shadow of the EHLA process. On this basis, we outline a pipeline for unsupervised anomaly detection and event diagnosis that works without extensive labeled data and can issue warnings when deviations occur. The article provides an architecture, an integration guideline, and experiences for brownfield plants and shows how minimally invasive sensor technology and analytics pave a robust path to inline quality assurance and, in the long term, to stabilization in a closed control loop.

**Biography**
Max Gero Zimmermann, born in 1990, grew up in Bonn and studied mechanical engineering at RWTH Aachen University (M.Sc., 2021), specializing in product development and quality assurance. Since 2022, he has been working as a research assistant at the Fraunhofer Institute for Laser Technology ILT in Aachen, in the laser deposition welding department. His research focuses on the digitalization of laser-based coating and repair processes: He develops sensor-based monitoring concepts, model-based strategies for process control, and AI-supported evaluation methods to improve the quality, efficiency, and sustainability of additive manufacturing.