VRIJE UNIVERSITEIT BRUSSEL

The faculty of Engineering of the Vrije Universiteit Brussel invites you to attend the public defense leading to the degree of

DOCTOR OF ENGINEERING SCIENCES

of **Jorge Sánchez Medina**

The public defense will take place on **Wednesday 11th June 2025 at 5pm** in room **I.0.01** (Building I, VUB Main Campus)

To join the digital defense, please click here
Meeting ID: 346 829 235 825 3
Passcode: aa6uS7id

STUDY AND DEVELOPMENT OF REAL-TIME MONITORING AND CONTROL METHODS IN FIELD-PROGRAMMABLE GATE ARRAY FOR LASER-BASED DIRECTED ENERGY DEPOSITION

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Abstract of the PhD research

Laser-based Directed Energy Deposition (DED-LB) is a metal additive manufacturing process, often referred to as "metal 3D printing." It builds three-dimensional objects layer by layer by directing thermal energy from a coaxial laser to create a melt-pool into which metal powder is deposited. This process allows for high material efficiency and precise control, making it ideal for applications requiring complex geometries and customized components.

As DED-LB technology continues to advance and achieve broader industrial adoption, in-situ monitoring and real-time process control are becoming critical for improving production efficiency, enhancing print quality, reducing reliance on costly non-destructive testing, and accelerating certification and qualification processes. This research aims to develop and evaluate real-time monitoring and control methods capable of addressing the challenging timing requirements of DED-LB process dynamics and assessing their impact on melt-pool characteristics and print geometry. The work is guided by objectives that include meeting hardware and process timing constraints, balancing estimation accuracy with implementation complexity, identifying appropriate sensor technologies, and validating system performance under real deposition conditions.

This dissertation leverages a combination of visual and hyperspectral cameras for non-contact melt-pool sensing, integrated with a high-performance electronic platform, the Field-Programmable Gate Array (FPGA), to manage the demanding real-time image processing and communication tasks required during monitoring and control. The research systematically investigates and compares melt-pool size and temperature monitoring techniques, offering detailed FPGA-based implementation strategies. These designs are presented with accessibility in mind, providing clarity for researchers and practitioners unfamiliar with FPGA systems. Additionally, a comprehensive analysis is conducted to benchmark hardware resource utilization against existing literature.

The study critically examines state-of-the-art methods, identifying key research gaps, particularly in the application of visual and hyperspectral imaging for melt-pool monitoring. In addition to this analysis, a closed-loop control system based on melt-pool temperature feedback is implemented to enable in-situ evaluation and validation of the proposed monitoring approaches.

The results offer valuable insights into melt-pool behavior during DED-LB, highlighting their influence on final part quality and process stability. This research provides a solid foundation for advancing real-time control in DED-LB processes, formulating practical recommendations for future studies, and contributing to the broader adoption of in-situ monitoring technologies in metal additive manufacturing.