Call for a Master’s intern with possible conversion to Ph.D.

Summary of the position and institute

- A master’s level internship project with possible conversion to a Ph.D.
- Supervisors: Manas V. Upadhyay and Daniel Weisz-Patrault
- Affiliation: LMS, CNRS, École Polytechnique, Institut Polytechnique de Paris
- Tentative start date: January-February 2025 (for internship) and September 2025 (for Ph.D.)
- Expertise sought: Background in Solid Mechanics, Computer Science, Applied Mathematics or equivalent

General context

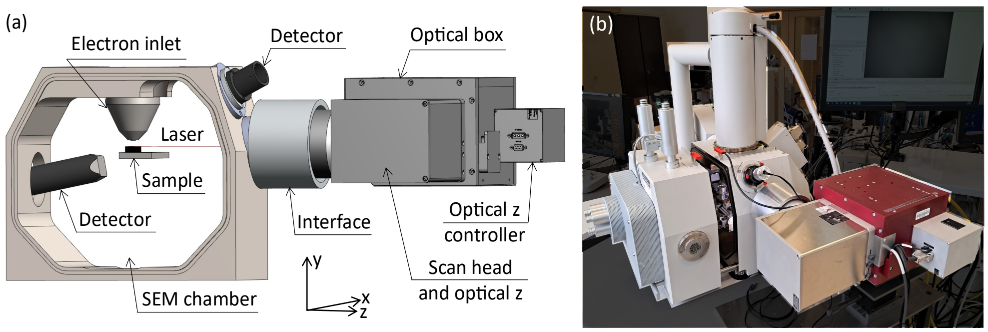

Figure 1: Novel CW laser-SEM coupling taken from [2]; illustration of the CW laser-SEM coupling (a) and image of the experimental setup (b).

Identifying the process-microstructure-(mechanical) properties relationship during metal additive manufacturing (AM) has been a significant challenge since the advent of this fabrication technology. Existing approaches to establish this understanding rely either on trial-and-error experiments or a combination of different multi-scale physics-based modelling approaches that are costly in resources and time.

At the LMS laboratory, we have recently developed a novel coupling between a continuous-wave laser with a scanning electron microscope (CW Laser-SEM in Figure 1) [1,2] in order to study microstructure evolution during laser scanning under highly controlled conditions and identify the micromechanisms occurring during heat-matter interactions. In one of the first studies conducted with this device, experiments were performed to validate a coupled computational fluid dynamics and phase-field model to study grain structure formation in 316L stainless steel [3] as well as an elasto-viscoplastic finite element model [4] to study intergranular stress and plastic deformation formation due to lasering.

However, the aforementioned modelling approaches are highly time consuming and impractical to establish a wide range process-microstructure-properties relationship map. To that end, this project aims at developing and using a workflow involving very fast and more economical surrogate models and later machine learning approaches in synergy with experiments.

Project and tasks

The CW Laser-SEM provides a unique opportunity to generate a database correlating laser scanning process parameters and microstructure, similar to [2, 3], that can be used to develop and validate rapid surrogate (reduced order) models for grain growth during fast solidification akin to [5]. Once validated, these surrogate models can be used to generate orders of magnitude larger datasets to train machine learning models that will be used to predict grain structure and mechanical properties as a function of AM processing parameters. Such an AI-driven strategy can then be employed in an optimization loop to fine-tune process parameters and achieve the desired microstructure and mechanical properties.

In the Master’s internship, that may continue into a Ph.D., the selected candidate will work on performing a thorough literature review on existing machine learning methods applied to identification of microstructural features and implement a machine learning model to identify geometric features of grains in alloys from SEM datasets.

In the Ph.D., this model will be generalized to other microstructural features, a workflow (akin to Figure 2) will be established and a thorough validation will be performed. More details on the project will be provided during the interview to shortlisted candidates.

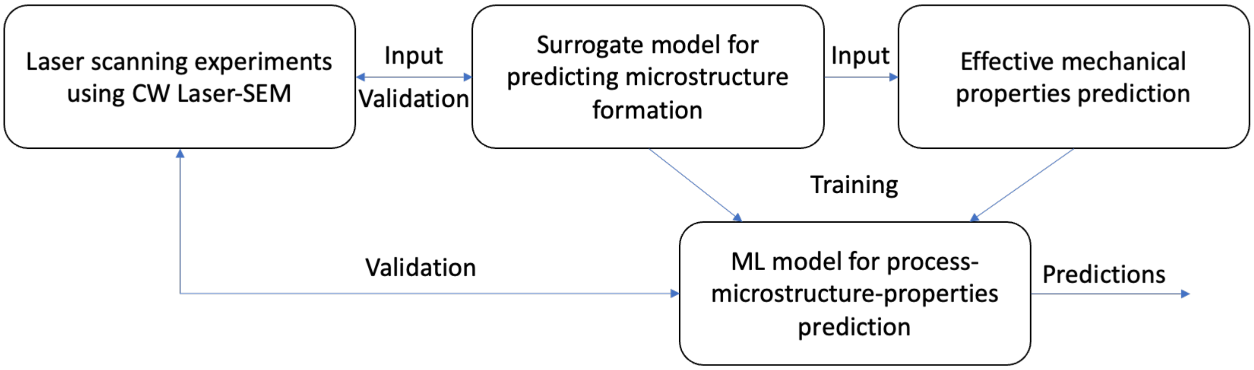

Figure 2: Workflow for the Ph.D. project

References:

[1] Patent (under evaluation): A. Tanguy, M. V. Upadhyay, J. G. Santos Macías, "System to treat samples using a continuous-wave laser and characterize them using an SEM". Submission date: 16 Dec 2022
[2] J. G. Santos Macías, A. Tanguy, K. Chen, L. Cornet, M. Vallet, M. V. Upadhyay. "Post-process lasering improves strength-ductility tradeoff and fatigue limit of additively manufactured stainless steels." Preprint: https://hal.science/hal-04530203
[3] A. F. Chadwick, J. G. Santos Macías, A. Samaei, G. J. Wagner, M. V. Upadhyay, P. W. Voorhees. "On microstructure development during laser melting and resolidification: An experimentally validated simulation study", *Acta Materialia* 282 (2025) 120482 https://doi.org/10.1016/j.actamat.2024.120482
[4] N. Mohanan, J. G. Santos Macías, J. Bleyer, T. Helfer, M. V. Upadhyay. "Intergranular stress and plastic strain formation during laser scanning of additively manufactured stainless steel: An experimentally-driven thermomechanical simulation study", *Materialia* 34 (2024) 102082 https://doi.org/10.1016/j.mtla.2024.102082
[5] Dollé, Q., & Weisz-Patrault, D. (2024). Very fast simulation of growth competition between columnar dendritic grains during melt pool solidification. Computational Materials Science, 243, 113112
https://doi.org/10.1016/j.commatsci.2024.113112

Candidate profiles

- A second-year Master's student in Solid Mechanics, Computer Science, Applied Mathematics or equivalent obtained after January 2024. Interested candidates graduating before January 1, 2025 can also apply.
- Proven skills and experience in implementing codes via Python or C++.
- A background or certification in machine learning would be a strong advantage.
- Very good communication (oral and written) skills in English. Applicants from non-English speaking countries should provide factual information on their proficiency in English.

Interested candidates please send an email to the address below with

- 1-page motivation letter
- Up-to-date and detailed CV
- Contact information of at least 2 referees willing to provide recommendation letters on your behalf

manas.upadhyay(at)polytechnique.edu and daniel.weisz-patrault(at)cnrs.fr