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**PhD course of National Interest in Technologies for
Fundamental Research in Physics and Astrophysics**

Annual report

Name and surname: Davide Cester
Cycle and a.a.: 40° Cycle, 2025/2026
Supervisor: Serena Graziosi, Pietro Rebesan

- Research activity carried out during the year**

The main objective of my PhD project is to explore the potential of the Powder Bed Fusion-Laser Beam of Metals (PBF-LB/M) technology, in combination with dedicated design tools and methodologies, in supporting the development of lattice structures, or more generally, metamaterials, with varying degrees of complexity. Specifically, I am currently focused on the design, optimization, and production of these structures with the intent of understanding how process parameters influence the geometrical, dimensional, and mechanical properties of these structures. Inconel 718, a nickel-based superalloy, is currently being selected as the reference material for producing these structures due to its excellent mechanical properties and oxidation resistance at high temperatures, which make it particularly suitable for extreme applications in nuclear physics and the aerospace industry. Given the complexity of these structures and the small size of their constituent elements, the issues of process-induced defects and dimensional tolerances are even more critical and significantly affect the performance of the final components.

An extensive literature review has been first conducted, and it is continually updated, to place this research activity within the broader field of applications and properties of such complex cellular structures. A focused analysis on Inconel 718 3D-printed lattice structures has also been performed. This review has highlighted that a significant challenge still exists concerning the development of these structures, which is the difference between their expected and real properties, often due to the lack of printing parameters optimization or inherent process limitations.

Therefore, this first year of the research has been dedicated to exploring the main process parameters influencing the result of the printing process. In particular, the process parameters to be set in order to achieve a relative density exceeding 99.5% with respect to the bulk Inconel 718 material, have been identified. Subsequently, several benchmark samples (e.g., thin and inclined walls, struts, hollow cylinders) were fabricated to evaluate surface quality and deviations from the nominal dimensions of the digital models. Optical microscope and Scanning Electron Microscope were used to detect internal and surface defects and a Coordinate Measuring Machine (CMM) was used for dimensional accuracy analysis.

The final step of this initial phase has involved the design of the first lattice structures using “Grasshopper”, the visual programming environment of the CAD (Computer Aided Design) software Rhino (www.rhino3d.com). Besides, some preliminary attempts to manufacture



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these lattices have also been performed. Future developments will continue to focus on the fabrication of these structures and their dimensional, microstructural, and mechanical characterization.

At present, the main challenges encountered have been related to the definition of the experimental workflow to follow due to the limited standards available related to this technology, and the identification of an appropriate process parameters' window for the lattice structure fabrication. While the former issue was addressed through targeted research on scientific publications focused on presenting benchmark samples to be used for this type of study, the latter is still under investigation and may require further refinement of parameters in the next planned experimental activities.

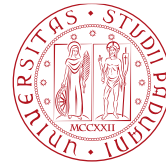
In parallel with this research activity, in collaboration with the INFN Section of Padua, I am working on the thermo-structural optimization of Multi Beam (MBTL) Mirror components for the DTT (Divertor Tokamak Test) project, a nuclear fusion experiment under construction at the Frascati ENEA Research center. DTT consortium is made up of 11 members, involving the main Italian research institutions, the research consortia, some prestigious universities and the most important Italian energy company. Mirror components must ensure the proper operation of the Electron Cyclotron Heating (ECH) system and the stability of the reflection of incident microwave beams inside the facility. Regarding this activity, my work has primarily focused on redesigning the cooling system and reinforcing the bottom section, with the goal of minimizing thermal gradients within the component and, consequently, reducing operational distortions. To perform this redesign activity, the Siemens® NX software was used.

Alongside the redesign, stationary thermo-structural simulations were implemented in the Ansys® Mechanical R1 2023 program. Some of the difficulties faced in this context included the implementation of the power load of the incident beams in the Ansys® environment and the optimization of the cooling system in the Siemens® NX software. These challenges were overcome in collaboration with other colleagues involved in the DTT project who already had experience with these components, and by looking at similar case studies from tutorials available online and publications.

- **List of attended courses and passed exams**
 - Python for numerical heat transfer modeling and building physics
 - Generative design for smart Additive Manufacturing
- **List of attended conferences, workshops and schools, with mention of the presented talks**



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International Doctorate Summer School “Geometrical Aspects of Architecture and Structural Mechanics”, Granada 19 – 23 May. No talk was given. I presented a poster focusing on my research activity.

- **List of published papers/proceedings**

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- **Thesis title (even temporary)**

‘Advanced Design for Additive Manufacturing approaches for cutting edge applications in physics and engineering’

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Date, 18/9/2025

Signature...

David Litz

Seen, the supervisor

Silvia Grassi