Development of X-ray phase-contrast imaging method for the analysis of lightning-struck aeronautical materials

Référence : **PHY-DPHY-2024-01**

Beginning: 2024 – Acquired financing (ANR)	**Deadline for application:** Dec. 2024

Key words: X-ray imaging, advanced optical methods, phase extraction methods, carbon composite, thermo-mechanical damage, lightning, radiation-matter interaction.

Profile and skills required: The student must have:

- a strong interest in image processing and coupled modelling/experimentation approach
- a background in physics (optics/plasma physics/ionizing radiation-matter interaction/metrology) that may include notions of materials science
- good knowledge of computer programming languages (Python / C, C++, Matlab...).
- knowledge of Monte Carlo particle transport codes would be a plus.

At the end of the thesis, the student will have developed skills in:

- X-ray non-destructive testing on an emerging topic with strong industrial demand
- wave front analysis methods
- composite materials and the physics of their damage
- data processing and modelling
- problem-solving, teamwork, project management, oral and written communication.

Presentation of the doctoral project, context and objectives:

Replacing aluminum by carbon fiber composites (CFRP) in the aeronautic industry is a research effort towards **sustainable aviation**. But compared to aluminium, CFRP have lower thermal and electrical conductivities and a sheet-like structure, meaning that there is a larger risk of thermo-mechanical damage if lightning strikes occur. A better **understanding of the physical phenomena** leading to this type of damage would enable aircraft manufacturers to make a reliable assessment of the type of lightning protection they need to put in place to further optimize aircraft weight and materials management.

In situ investigation of materials requires the use of X-rays. However, images of CFRP, which are light materials, have low contrast if the imaging method is based solely on **X-rays absorption** (absorption contrast imaging or radiography). ONERA and CEA are therefore developing innovative imaging methods that also exploit **X-rays deflection** (phase contrast imaging or XPCI). The related imaging bench has recently provided tangible results to characterize the **core damage** of CFRP stricken on the ONERA lightning test bench (post-mortem analysis). These results have aroused strong industrial interest and led to the award of an ANR research grant.

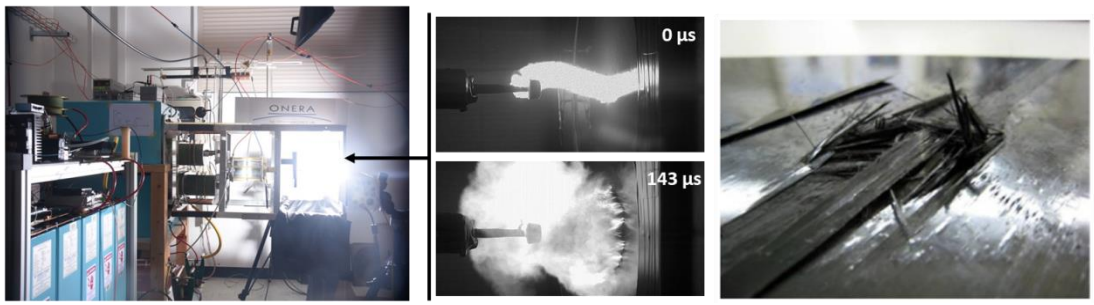

Figure 2 : Photograph of a lightning strike on ONERA's lightning bench and damage to a CFRP panel struck by a 40,000 ampere arc.

In this thesis, you will use the XPCI numerical simulation tools of CEA and material damage tools of ONERA to develop **XPCI imaging of CFRP impacted by lightning**. The modelled images will be compared with experimental images to **help in the interpretation and analysis of damage**. Developments will be guided by the long-term objective of dynamically imaging CFRP damage during lightning strikes on ONERA's lightning test bench.

References:

[1] L. Chemartin et al., Direct Effects of Lightning on Aircraft Structure: Analysis of the Thermal, Electrical and Mechanical Constraints, AerospaceLab, p. 1-15 (2012)

[2] R. Sousa Martins, Etude expérimentale et théorique d'un arc de foudre et son interaction avec un matériau aéronautique, Thèse Université Paris-Saclay (2016).

[3] A. Momose, Recent Advances in X-ray Phase Imaging, Jpn. J. Appl. Phys. 44, 6355 (2005)

[4] A. Stolidi et al., "Confidence map tool for gradient-based X-ray phase contrast imaging." Optics Express 30, 4302 (2022)

[5] G. Giakoumakis et al., "Artifacts reduction in high-acutance phase images for X-ray grating interferometry." Optics Express 30, 41147 (2022)

[6] A. Stolidi et al., "X-ray phase contrast imaging model: application on tomography with a single 2D phase grating", 11th Conference on Industrial Computed Tomography, Wels, Austria (iCT 2022)

[7] https://www.esrf.fr/BAG/MI1397

Possible collaborations

ONERA/DOTA, ONERA/DMAS (Materials and Structures Department), CEA List, ESRF

Welcome Laboratory at ONERA

Department : Physics, Instrumentation, Environment, Space

Place : Palaiseau

Contact of the supervisor: Amélie Jarnac

Phone : 0180386430 Email : amelie.jarnac@onera.fr

PhD director

Name : Adrien Stolidi

Laboratory : CEA List

Phone :

Email : adrien.stolidi@cea.fr

Pour plus d'informations : https://www.onera.fr/rejoindre-onera/la-formation-par-la-recherche