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THE FRENCH AEROSPACE LAB

PROPOSAL FOR AN INTERNSHIP

Reference : **DPHY-2023-28**

Place : ONERA Palaiseau & CEA Saclay

Department/Dir./Serv.: DPHY/FPA

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INTERNSHIP DESCRIPTION

Topic(s) : Lightning damage, carbon composite, Radiation-matter interactions, Optical methods

Level: ☒ Master 2 ☐ L3-M1 ☐ Other

Title: X-ray phase contrast imaging of aeronautical structures for lightning damage analysis

An aircraft is stricken by lightning every 1500 hours of flights. Depending on severity, the aircraft can be grounded for several days. The severity is increased when fuselages are built from carbon composites compare to traditionally used aluminium. However, the use of carbon composites has rapidly increased to lighten the weight of aircraft and reduce fuel consumption. Hence protecting planes against lightning is a matter of safety and sustainability. One strategy is to understand the thermo-mechanical damage of lightning [1] on carbon aeronautical structures. ONERA is equipped with a lightning test bench and develops dedicated instrumentation to characterize the dynamics of lightning damage [2]. The instrumentation has to fulfil two constraints: i) the lightning tests are destructive and require a self-sufficient data set for each shot; ii) the time scale of the phenomena ranges from microseconds to milliseconds. These constraints impose to use high speed cameras that operate in the visible range of the electromagnetic spectrum, where the structures are opaque and the lightning arc is luminous. Thus, the core damages are only studied through indirect measurements and their thermo-mechanical origins remain unknown. To shed new light on these phenomena, the development of dynamic X-ray phase contrast imaging (XPCI) is needed.

Dynamic XPCI can only be found in some synchrotrons. The challenge is to bring this type of measurement in a laboratory. Since 2013, a collaboration between ONERA and CEA aims at developing static XPCI laboratory methods [3, 4]. The associated bench has recently provided tangible results to characterize the core damage of structures stricken on the ONERA lightning test bench (post-mortem analysis). This internship is part of the development scheme of a high-speed XPCI laboratory bench (> 500 kHz) to characterize the core damage in real time, on the lightning test bench of ONERA. The direct consequence of ultra-high speed imaging is the reduction of exposure time. Due to the decreased signal-to-noise ratio, the main challenge is to obtain phase information of sufficient quality. The internship aims at numerically studying XPCI of carbon aeronautical structure in order to i) simulate and define a XPCI laboratory bench which fits high-repetition rate requirement, ii) simulate the image of a modelled aeronautical structure and produce first experimental validations, iii) develop advanced phase retrieval algorithms extract to phase information in high noise conditions. To get there, this will involve getting familiar with X-ray phase contrast imaging methods; sizing a dynamic imaging bench (spectral shaping, flux calculation, detector dimensioning, etc.) using the numerical tools of ONERA and CEA and a state-of-the-art technological survey; validating the sizing by reproducing reference X-ray phase contrast images.

To carry out this work, the student must have knowledge in ionizing radiation/matter interactions and/or optical methods as well as computer programming languages (Python / C, C++, Matlab...). Knowledge of Monte Carlo particle transport codes would be a plus. The trainee will receive a monthly stipend.

[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] Stolidi, Adrien "Développement de méthodes d'imagerie par contraste de phase sur source X de laboratoire." Thèse, Université Paris Saclay, 2017.

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

Is it possible to work in pairs? no

Methods to be implemented :

☐ Theoretical research	☒ Synthesis work
☒ Applied research	☒ Documentation work
☒ Experimental research	☐ Participation in a production

Possibility of PhD thesis : **Yes**

Length : Minimum : 4 month Maximum : 6 month

Preferable period : March – July 2023

INTERN'S PROFILE

Required knowledge:	**Desired schools or institutions:**
Ionizing radiation/matter interactions and/or optical methods as well as computer programming languages (Python / C, C++, Matlab...). Knowledge of Monte Carlo particle transport codes would be a plus	Master 2 with an emphasis on Physics, Metrology, Material science, Programming.