Institut
Sciences de la Fusion et
de l'Instrumentation en
Environnements Nucléaires
Aix-Marseille Université

PHD POSITION

Emissivity behavior of materials submitted to hostile conditions

- **RESEARCH FIELD(S):** Physics, thermal characterization, radiative properties, fusion
- **JOB LOCATION:** AMU-IUSTI (70%), CEA-IRFM (30%)
- **CONTRACT AND SALARY:** Aix-Marseille University's 3 years PhD contract

ABSTRACT: Infrared (IR) thermography is widely used in fusion research to study the heat load distribution on the plasma facing units (PFU) as well as ensuring their protections [1]. To these ends, assessing the emissivity of tungsten (W) components, as used for the ITER divertor, is necessary to derive accurate surface temperature from thermal radiation measured by infrared systems. The W emissivity is low and depends on various parameters as wavelength, temperature, and surface state such as its composition (oxidation, impurities) as well as its structure (roughness, cracks, deposited layers [2]). During plasma operation, the PFU surface state is expected to evolve as function of time because of the plasma wall interaction processes which are likely different from pulse to pulse. Consequently, this is strongly affecting the emissivity value and distribution [3]. As a first step, a dedicated setup was developed and applied to measure the emissivity of W samples representative of the WEST lower divertor, including samples with different damage levels generated by electron gun (micro-cracks and crack network) [4]. The experimental results showed, as expected, the dependencies with wavelength, temperature and surface state (roughness, cracks, pollution by impurities). For the same wavelength and temperature, the surface state showed a strong influence with a large increase of the emissivity with the micro cracks and crack network, by a factor up to 4. However, the samples used in this study did not see plasma operation that could have modified the surface state through plasma surface interaction (erosion, deposition and possible damages). As a second step, an in-situ method was achieved to assess the emissivity evolution of the WEST divertor PFUs [5] during the first phase of WEST. The method is based on the measured infrared (IR) radiance, coming from isothermal PFUs at several temperature levels, to be compared with embedded thermal sensors before each pulse with the consideration of multiple reflections through photonic modelling. Based on this method an emissivity monitoring was performed during an experimental campaign of WEST. This monitoring has expectedly shown strong correlation of the emissivity distribution to the plasma operation, especially for the strike point location, plasma species and plasma current. Emissivity distribution from 0.12 to 0.65 was observed on a single PFU in few cm as well as emissivity variation at a day scale even in the main erosion area of the outer strike point (low field side). A third step relying on post-mortem measurements started since the whole PFU divertor of WEST was removed from the machine to install the actively cooled ITER-like PFU. The objective of this third step is to accurately evaluate the emissivity in laboratory and his distribution to the surface state pollution and structure.

The main objective of this thesis is to gain a better understanding of the variations in emissivity of materials subjected to extreme conditions, in particular of tungsten coming from Tokamak such as WEST. To this end, measurements on components subjected to high heat flux and special conditions will be characterized from a structural, chemical and thermal point of view.

The PhD student will have to become familiar with the scientific setups for carrying out all these measurements. First, the emissivity of the surfaces will be measured in the IUSTI laboratory thanks to an existing experimental bench that will have to be upgraded, in particular to access the spectral emissivity. Then, structural and spectroscopic surface analyses will be realized in the PIIM laboratory and the electron microscopy platform. For the structural part, AFM, confocal microscopy, SEM and possibly X-ray microtomography will be used for the characterization of the surface state (deposit, crack networks, microcracks…). In the case of the surface composition and the presence of oxide layers, EDX and Raman spectroscopy can be used. All these analyses will have to be performed both on samples prepared in the laboratory, in particular to study the influence of the thickness of an oxide layer, and on components that have undergone transformations in the WEST tokamak. The aim of the thesis will be to link the emissivity evolutions measured in-situ (and also post-mortem) to the plasma scenarios. Comparison with plasma wall interaction modelling (such as SOLEDGE-EIREN + ERO2.0) will help to understand the full map of emissivity (impurity transport in the edge plasma) as well as local distribution patterns (local erosion and redeposition).

Furthermore, as this subject is part of a much larger project aiming to characterize thermal and radiative properties as a function of the extreme conditions occurring in fusion and fission applications, the PhD student will be able to test their methods on samples coming from fission research reactors within the framework of another PhD thesis at the IM2NP laboratory. Moreover, the PhD student will work in collaboration with a post-doctoral fellow from the 2nd year of this thesis. The post-doctoral fellow will work on thermal properties such as diffusivity, heat capacity and conductivity for fusion and fission applications for the three laboratories involved.

References:

[1] M.H. Aumeunier et al., "Infrared Thermography in Metallic Environments of WEST and ASDEX Upgrade", Nuclear Materials and Energy 26 (2021) 100879. https://doi.org/10.1016/j.nme.2020.100879

[2] C. Martin et al., First post-mortem analysis of deposits collected on ITER-like components in WEST after the C3 and C4 campaigns Phys. Scr. 96 (2021) 124035

[3] N. Fedorczak et al., "Infra-red thermography estimate of deposited heat load dynamics on the lower tungsten divertor of WEST", Physica Scripta T171 (2020).

[4] J. Gaspar et al., "Emissivity measurement of tungsten plasma facing components of the WEST tokamak", Fusion Engineering and Design 149 (2019) 111328.

J. Gaspar et al., "In-situ assessment of the emissivity of tungsten plasma facing components of the WEST tokamak", Nuclear Materials and Energy, 25 (2020) 100851.

QUALIFICATIONS & RESERACH REQUIREMENTS: The candidate must have a physicist profile and knowledge in materials science, optics, thermodynamics and heat transfers. Knowledge of signal processing, MATLAB / Python language, LabVIEW software will be a plus. He (she) must be motivated to carry out both theoretical and experimental work. A good command of written / spoken English is essential, as well as a good aptitude for teamwork in an international environment.

- **APPLICATION DEADLINE**: No deadline

- **STARTING DATE:** From 10/2022 to 12/2023

- **REQUESTED DOCUMENTS OF APPLICATION:**
  - Bachelor and Master grades
  - Cover letter & Curriculum Vitae
  - One or two recommendation letters
  - If available, the internship report at the end of the Master degree will be appreciated.

- **CONTACT TO APPLY (EMAIL OR WEBSITE)**:
  - Please send any information request at the following addresses: Jonathan.gaspar@univ-amu.fr, jean-laurent.gardarein@univ-amu.fr, isfin-direction@univ-amu.fr