Infrared Thermography in Metallic Environments of WEST and ASDEX Upgrade

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Infrared (IR) thermography is a widely used tool in fusion devices to monitor and protect the plasma-facing component from excessive heat loads. However, with the use of all-metal walls in fusion devices, deriving surface temperature from IR measurements has become more challenging. This is due to two main limitations: the measurement is perturbed by the surrounding thermal radiations reflected by the surface and the temperature calculation depends on the target emissivity, which can range from ~ 0.05 to 0.4 (for a pure Tungsten surface).
In this paper an overview of infrared measurements in the metallic tokamaks WEST and ASDEX Upgrade (AUG) is reported and the techniques carried out in the modeling and experimental fields to deal with this radiative and fully reflective environment are presented.
1) Experimental characterizations of metallic samples with different roughness have been first carried out to establish a comprehensive model of emission and reflectance as a function of the temperature, wavelength and incident/observation direction. The first results show that the emissivity on Tungsten samples does not vary with the wavelength in the spectral range of 3 to 5 µm whereas it varies with the temperature following already established theoretical models. The measurements also reveal that the behavior of emission and reflectance varies significantly with sample roughness and cannot be predicted with the present state of knowledge.
2) In parallel, a synthetic IR diagnostic has been developed, including the full measurement chain. First, heat loads on Plasma Facing Components (PFCs) are computed using a 3D magnetic field line tracing. Then, the surface temperature is estimated from finite elements of thermal calculations. Finally, the instrumental transfer function is taken into account, in addition to the influence of thermal-radiative properties of in-vessel components, and simulations of photon-wall interactions. The comparison between the expected heat load pattern and the associated surface temperature through the modelling and the experimental results are reported for experiments on WEST and AUG. The synthetic diagnostic has first confirmed and/or proven reflection patterns in the IR image and their origin. For instance, it has shown that a large number of hot spots on the WEST wide-angle IR view originate from the outboard antenna protection limiters, affecting several other PFCs. This modeling tool has also demonstrated that particular attention should be paid, in both WEST and AUG, when monitoring beveled PFC with unexpected light pattern on the leading edges. The simulation shows that this is not due to an abnormal thermal event but involves the angular dependence of the emissivity, which can change with the surface state. Assessing accurately the impact of the radiative metallic environment is therefore crucial both for machine protection and physics studies based on infrared measurements.