FUSION TECHNOLOGY DESCRIPTION

EUROfusion
TECHNOLOGY TRANSFER PROGRAMME

Infrared measurement synthetic database for inverse thermography model based on deep learning

CEA developed an innovative infrared (IR) measurement technology using Artificial Intelligence from the MHD code JOREK. Addressing challenges in metallic environments, it employs a numerical approach for accurate temperature measurement. Applied on the tokamak WEST in fusion research, this system showcases robustness in extreme conditions. Beyond fusion, it holds promise for industrial applications, facilitating precise surface temperature monitoring on production lines and additive manufacturing devices.

Description of the technology

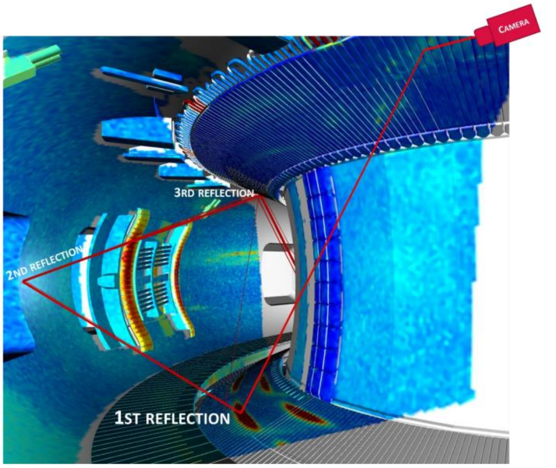
There are issues with IR measurement in metallic environments due to low and variable emissivity of targets and reflection contributions, causing major errors in temperature measurement. This novel numerical approach is based on an infrared synthetic diagnostic (or forward model), able to provide realistic simulated infrared images from a given plasma scenario. This tool allows us to understand and quantify the impact of different disruptive phenomena involved in the measurement chain.To remove those reflection features of IR images and retrieve surface temperature, this method is based on an inversion algorithm from Artificial Intelligence techniques from the MHD code JOREK.

Two main effects are taken into account in the realistic thermal scene modeling:

- The environment with the surrounding thermal scene
- The instrument itself (optical transfer functions, calibration uncertainties)

At first, the thermal space is modeled in 3D geometry based on Finite Elements or Finite Volume Methods. Then the properties of the material are defined by the Bidirectional Reflectance Distribution Function (BRDF) which describes the photon behavior on a surface for any incident and viewing direction and is a determinant factor for the fidelity of ray-tracers and the understanding/simulation of the optical measurements.
An advanced camera model has been then developed that includes distortion parameters, as well as a new tool to adjust automatically the 20 parameters of the camera. This allows aligning synthetic images with an accuracy better than 10 pixels on high-resolution images 1280x1024 of 4 mm pixel resolution

Inversion algorithms are also developed in order to retrieve surface temperature from experimental images. Such techniques should be able to handle parasitic flux coming from reflections and uncertainties on targets emissivity. The construction of inverse models is based on synthetic images, able to simulate all possible scenarios.
With the new results applied on synthetic IR images of WEST wide angle tangential, considering realistic surface properties: all reflections patterns are removed, and surface temperature is retrieved with an error better than 6% on 10000 images test.



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Innovation and advantages of the offer

Thanks to the deep learning method, this approach can adapt to harsh environmental circumstances, and it has provided realistic simulated infrared images This advanced data processing has shown its robust capacity and real reliability to determine precisely IR temperature measurement. In consequence, this approach will be part of a new IR module on CIVA-CEA software.

The key point for these methods is to get an extensive training database of simulated infrared images covering all scenarios and changes properties. To reach this objective, robust thermal scene modeling is required with a precise characterization of materials optical properties, able to deal with the wide diversity of conditions during the operation.

Non-fusion Applications

This system holds potential for industrial use, offering precise surface temperature monitoring with applications such as overseeing heating processes on production lines and additive manufacturing devices.

EUROfusion Heritage

The infrared (IR) thermography system on ITER has been designed to monitor ~70% of the first wall and diverter surfaces. It should be capable, of measuring surface temperature with sufficient accuracy to detect anomalous behavior of Plasma Facing Components (PFCs) between 200 to 3600°C. This work has been carried out within the framework of the EUROfusion Consortium, funded by the European Union via the Euratom Research and Training Programme (Grant Agreement No 101052200 — EUROfusion).

This work has been carried out within the framework of the EUROfusion Consortium, funded by the European Union via the Euratom Research and Training Programme (Grant Agreement No 101052200 — EUROfusion). Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Commission. Neither the European Union nor the European Commission can be held responsible for them.