Unveiling Precision with the Very High-Resolution Infrared Imagery

Developed for nuclear fusion research, the Very High-Resolution Infrared Imagery (VHR) enhances precision in monitoring Plasma Facing Units (PFUs) misalignment and localized high heat fluxes. With a lower temperature detection threshold and high spatial resolution, the VHR enables detailed analysis and visualization of toroidal MonoBlock length. Beyond fusion, this technology finds applications in diverse industries, including steel, cement, and glass, offering improved temperature control and process optimization, showcasing its robustness and efficacy in harsh environmental conditions.

Description of the technology

Plasma confinement in nuclear fusion poses considerable challenges, requiring meticulous control to heat it to 150 million Celsius degrees without damaging the tokamak's walls.The divertor, an essential part of the reactor, extract gaseous effluents, impurities and part of the heat generated. As a result, it needs to resist to the heat and to be well protected. However, a little misalignment of the Plasma Facing Units (PFUs) can lead to heat introducing between them and damage them from the side.

To simulate conditions with localized high heat fluxes, a metrological inspection monitored vertical misalignment between neighboring PFUs. This misalignment allows the magnetic field to impact monoblocks from the side, risking damage. The development of a Very High-Resolution Infrared Imagery (VHR) specifically for this experiment empowers scientists to study the phenomenon with maximum precision and obtain clear visualizations.

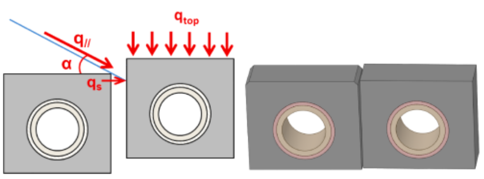

Figure 1 :
Left – Magnetic field line impacting the side of the misaligned monoblock (blue line) with a parallel heat flux coming from the scrape-off layer (q//) and an incidence angle (α).
Heat flux absorbed on the top surface (qtop), and on the side surface (qs) are also depicted on the misaligned MB.
Right – ITER-like PFU shaping used in WEST with chamfered edges: 1 mm × 1 mm on the left MB and sharp edges on the right MB.

The VHR was developped to have a better (lower) temperature detection threshold (Tbb = 250°C instead of 370°C) than the imagery used for previous experiments. This enable to use it in the full toroidal MB (MonoBlock) length in the maximum heat flux area. To reduce this threshold, the wavelength of the filter was changed from small wavelength infrared (1.6 to 2.1 µm) to medium wavelength infrared (3.9 ± 0.1 µm).
To get an accurate image, the VHR presents a high spatial resolution (pixel size = 0.091), which allows to analyze precisely and locate the high heat fluxes. Despite this, optical blurring and deformation can be observed on very steep temperature gradients.

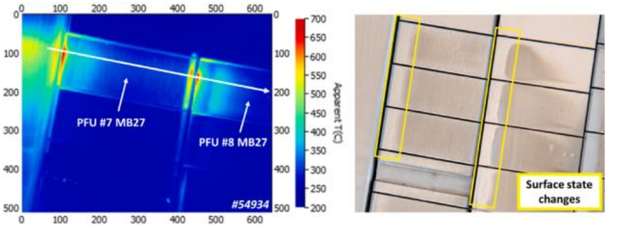

Figure 2 : Shot #54 934 on PFU #7 (chamfered edge – h = 0.28 mm) and PFU #8: (sharp edge – h = 0.40 mm).
Left: IR data frame (13.78 s) with MWIR filter (3.9 µm), which exhibits local heating on MB27.
Right: Picture of the FoV showing the different surface states.

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TECHNOLOGY TRANSFER PROGRAMME

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Innovation and advantages of the offer

This new developed VHR presents many advantages :

- Lower temperature detection threshold
- High spatial resolution (0.091 pixel size) enables precise analysis of heat fluxes.
- Filter wavelength adjustment enhances versatility.

Non-fusion Applications

For non fusion applications, this new imagery method offers new possibilities. It can be applied to all industries requiring temperature control, such as steel, cement, or glass industries, and Space. It could enable them to improve their process and reduce imperfections and errors.

EUROfusion Heritage

This innovation was developed to improve the researches in the WEST, which look to face challenges for ITER project. It takes part of an approach of continuous problem solving, related to all the obstacles we can already see for ITER project. This work has been carried out within the framework of the EUROfusion Consortium and has received funding from the Euratom research and training programme 2014-2018 and 2019-2020 under grant agreement No 633053.

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