

Improved performance of IRVB foils to image low- to moderate-temperature plasma radiation

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Newly designed foils have been developed for Infra-Red Video Bolometers (IRVB) deployed on MAST-U [1] and Wendelstein7-X, yielding twice the temperature rise and higher uniformity compared to previous best efforts [2], improving the accuracy of the local emissivity inference.

The IRVB maps the 2D plasma total emissivity by converting radiation to temperature rise of an absorber, then monitored by an IR camera. One was recently validated on MAST-U [3] and used to investigate the evolution of radiative detachment in the inner divertor leg [4].

A critical component is the radiation absorber foil, made of a high-Z layer and a blackening coating. As the signal is in the form of temperature rise, the SNR for low- to medium-temperature plasmas (≤ 2 keV, present in the edge of high power density tokamaks) is often limited by the minimum producible foil thickness [5].

We designed an innovative multilayer foil significantly thinner and more uniform, where the high-Z layer is produced via vapour deposition rather than mechanically [1], with blackening layer sized using previous inferences [6]. Tests on the new MAST-U foil showed, compared with previous iterations, a much smaller spatial variation of the thermal response (1.4% vs 13% variation across the whole foil of peak temperature, 1% vs 2.3% at its centre) enabling a simpler and more reliable thermal analysis [3], and about twice the temperature increase.

Calibration with a novel scheme [1] initially failed but was achieved after manually adding a further blackening layer, improving emissivity but reducing uniformity (6% across the whole foil and 2.4% locally). Calibration results were compared with an analytical model linking foil components and assembly thermal properties, allowing estimation of the global IRVB SNR. The additional blackening layer does not lower the peak temperature (due to low conductivity) but adds thermal inertia, slowing the foil response. Calibrated values are within $\sim 60\%$ of the estimate, with the IRVB SNR increasing on MAST-U by 20%, while remaining unchanged on W7-X, ultimately reducing the threshold for detectable radiated power signals. In both cases the foil is significantly more uniform, reducing the uncertainty in the foil spatial power distribution and in the spatial resolution of their tomographic inversion [3].

These results demonstrate that multilayer foils can be optimised based on plasma emission spectra and IRVB performance predicted. Further work is needed to optimise vapour-deposited blackening thickness and fully exploit this technique.

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[1] F. Federici, et al. *RSI*, 2024

[2] K. Mukai, et al. *RSI*, 2016

[3] F. Federici, et al. *RSI*, 2023

[4] F. Federici, et al. *NME*, 2025

[5] R. Sano, et al. *PFR*, 2011

[6] K. Mukai, et al. *RSI*, 2018

Specify category (Magnetic confinement fusion, Inertial confinement fusion, High-energy-density plasmas, Space plasmas, Astrophysics or Industrial applications, Others): Magnetic confinement