DEVELOPMENT OF INVERSE THERMOGRAPHY METHODS BASED ON INFRARED SYNTHETIC DIAGNOSTIC

M-H. AUMEUNIER
CEA/IRFM, Saint-Paul Lez Durance, Cadarache
Email: marie-helene.aumeunier@cea.fr

M. LE BOHEC, R. BRUNET, M. FORMOSA and the WEST team
CEA/IRFM, Saint-Paul Lez Durance, Cadarache

Y. GAO, A. PUIG SITJES, M. JAKUBOWSKI and the W7x team
Max-Planck-Institut für Plasmaphysik, Wendelsteinstr., Greifswal, Germany.

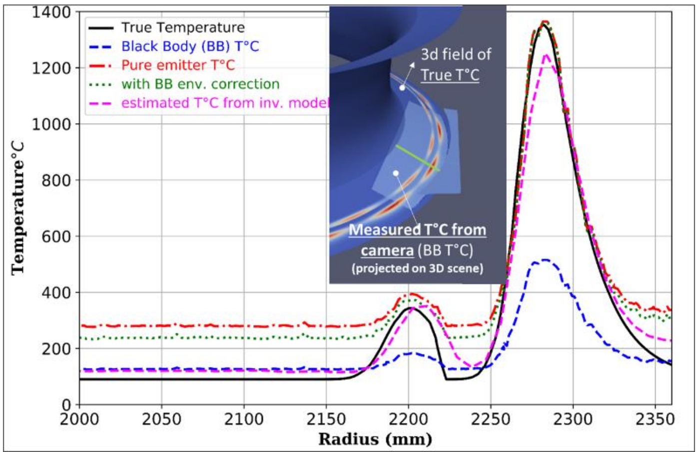
F. RIGOLLET
Aix Marseille Univ, CNRS, IUSTI, Marseille, France

Abstract

Infrared (IR) thermography system is a key diagnostic in fusion devices to monitor the Plasma Facing Components. Nevertheless, both the qualitative and quantitative analysis (i.e. the hot spot detection and the surface temperature measurement) are challenging due to the presence of disturbance phenomena as variable emissivity and multiple reflections in fully metallic environment. To do so, a synthetic diagnostic approach has been developed to assess accurately the abovementioned effects. Such synthetic diagnostic is an indispensable tool both for predicting and better understanding the wall heat loads but this is also the basis from which a general inverse model can be established for filtering reflections and getting more reliable surface temperature. IR synthetic diagnostic (i.e. forward model) and inverse methodology are two programs developed in parallel as they are benchmarked on existing devices as WEST and W7x.

IR synthetic diagnostic is based on Monte Carlo Ray Tracing (RT) codes coupled with the 3D field line tracing and thermal calculations. The accurate prediction of the measurements will depend on the capability of modelling all physical processes involved in the measurements, i.e.: (1) the plasma heat loads deposit and the resulting surface temperature of in-vessel components for different plasma scenarios (2) the radiative properties of materials (reflectance and emission model) managing photon-wall interactions (3) the production of synthetic images including camera and optical model. Several efforts have been made to consolidate the chain of calculations. First, on a theoretical point of view, physical models have been improved (e.g. the development of reduced and robust thermal model based on the Modal Identification Method). Moreover some parameters have been adjusted through the use of experimental data e.g. the fitting of Bidirectional Reflectivity Distribution Function from measurements performed on tungsten samples or the automatic adjustment of camera model from an experimental image. Applied on WEST and W7x devices, IR synthetic diagnostic made it possible to prove the multiple reflections features in the experimental images.

A first inverse model has been also established using an analytical reduced-model of radiative transfer assuming diffuse surfaces. A first proof of concept applied on WEST has shown that the temperature profile on the divertor can be estimated with an accuracy better than 30% on colder target at 90°C and better than 6% on peak temperature, which is a clear improvement compared to usual methods considering blackbody (BB) or pure emitter or yet with simple correction of reflected flux assuming uniform radiative black-body environment, as shown in figure below.



Further improvements are under going to consider specular surfaces in the same time as it is investigated deep-learning neural network trained from synthetic data sets derived from forward models (RT codes or reduced-model).