Synthetic X-ray tomography diagnostics for tokamak plasmas

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Tomography diagnostics represent an essential tool in tokamaks to infer the local plasma properties using line-integrated measurements from one or several cameras. In particular, soft X-rays (SXR) in the energy range 0.1 – 20 keV can provide valuable information on magnetohydrodynamic activity, magnetic equilibrium or impurity transport.

Modern tokamaks like ITER, JET or WEST use tungsten instead of carbon as the main plasma facing material in order to solve the tritium retention issue. However, tungsten impurities are a major source of concern due to significant radiation losses in the plasma core, thus they must be kept under acceptable concentrations. For instance, a small W core concentration of 3.10^{-5} increases by 20% the minimum triple product $nT\tau_E$ required to make the thermonuclear burn possible [1]. Therefore, 2D SXR tomography diagnostics become crucial to estimate the tungsten concentration profile in the plasma, quantify the 2D poloidal distribution and identify relevant impurity mitigation strategies [2].

Unfortunately, the local SXR emissivity reconstruction is an ill-posed inverse problem with usually a very limited number of measurements, requiring an adequate regularization procedure [3]. Moreover, the correct estimation of the local impurity concentration relies on the proper characterization of the detector spectral response as well as the detailed emissivity features of the plasma, namely the filtered impurity cooling factor. In this context, a synthetic diagnostic becomes a very valuable tool to study the tomographic reconstruction capabilities, to validate diagnostic design as well as to assess the error propagation during the impurity density reconstruction process [4].

The goal of this contribution is to give a didactic introduction to these topics with a focus on some applications and practical examples of synthetic diagnostic studies for soft X-ray tomography in tokamak plasmas.

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[3] M. Anton et al., Plasma Phys. Control. F. 38 (1996) 1849.
[4] A. Jardin et al., 2017 JINST 12 C08013.