DETERMINATION OF W CHARACTERISTICS IN WEST BY MEANS OF EXTREME UV EMISSION AND ARTIFICIAL INTELLIGENCE

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INTRODUCTION

With the choice of Tungsten as the main wall material of ITER and the subsequent equipment of several major devices (e.g. ASDEX-Upgrade, JET, WEST) with solid Tungsten or Tungsten-coated plasma-facing components, radiative losses and fuel dilution set limitations to the operational domain of fusion devices. It is hence essential to diagnose W transport and density in those devices. Contrary to other diagnostics (bolometry and most of soft-X ray diagnostics), Extreme UV (EUV) spectroscopy offers the advantage of providing information directly on W. The extremely complex spectral structure of W emission makes the measurement analysis complex and time consuming, but also it provides a wealth of information about its behaviour. In this article, we discuss three aspects of our W spectroscopic analysis focussed on the EUV spectrometer operated on WEST: *i)* modelling of a prominent W feature emitted at 45-65 Å by means of a method adapted from high-density (laser- and ICF) plasmas, *ii)* W density determination in the plasma core of routinely performed LH-heated plasmas, *iii)* electron temperature determination both from an emission model and from an artificial intelligence analysis. Those examples show that EUV spectroscopy measurements bring an essential contribution to the physics of many-electrons systems. From a more applied point of view, it is a unique technique for a detailed analysis of W transport and radiation in fusion devices. It is also well suited to more global consistency studies of plasma measurements.

COLLISIONAL-RADIATIVE MODELLING OF A QUASICONTINUUM FEATURE

WEST is equipped with two extreme-UV (EUV) spectrometers [1], one of which can scan the range 15-340 Å. It can be rotated around a horizontal axis so that its line of sight sweeps periodically the lower half of the plasma with a period of 4 s or more. It allowed observations of a W quasicontinuous feature at 45-65 Å already reported in many fusion devices (see e.g. [2, 4]). Collisional-radiative atomic physics calculations based on the usual atomic structure model fail to reproduce accurately the observations, possibly because the number of fine-structure energy levels to include would make the computation time and memory impractical. We have used semi-statistical methods [5] developed and used for high-density, high-Z plasmas to model spectra measured in WEST plasmas at 1 to 3 keV. With appropriate consideration to the important atomic configurations, the model provides satisfactory ab initio charge state distributions [6] and synthetises the observed two broad structures although with a slightly shifted wavelength and shape. Those differences are due to the use of a simple Hartree-Fock-Slater atomic potential in the calculations. Calculations using a more sophisticated atomic potential are underway.

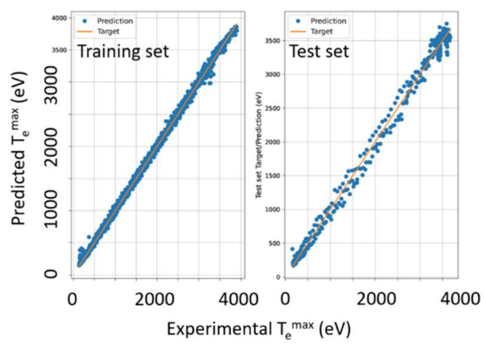
W DENSITY PROFILES

The observation of well resolved spectral lines of W^{42+} to W^{45+} with our EUV spectrometer allows to access the core plasma of routinely performed LH-heated plasmas with a central temperature above 3 keV. We have built a model of the emission of those lines, based on the electron density and temperature measurements by interferometry and electron cyclotron emission respectively on the one hand, and on the other hand on the commonly accepted ionisation equilibrium of W [2] and intermediate coupling calculations of the photon emission coefficients (PEC) of the observed lines. With the assumption of a weak W density gradient in the plasma core and by combining the information gotten from W^{42+} to W^{45+}, W density profiles are obtained close to the magnetic axis. With a 15 ms time resolution and a fixed, central line of sight, it is possible for example to evidence W accumulation in an ICRH-heated plasma [3].

An independent method has been developed to extract the W density from a combination of the (spectrally unresolved) soft-X ray and bolometry diagnostics. It draws advantage of the different electron temperature dependence of the total cooling function and its soft-X ray-filtered version. It is shown that this method can provide results between 2.5 and 4.5 keV due to contributions from light/mid-Z impurities dominating Tungsten line radiation below 2.5 keV and to the similarity of the temperature dependence of both cooling functions.

Beside the main diode-based SXR array, WEST is also equipped with a multi-energy SXR camera [4]. Tungsten density is inferred from energy-resolved measurements of this camera in the range 2-3 keV where the radiation is dominated by W line emission. W density is estimated by modeling the inverted radial emissivity profiles with an analytic SXR tomography code based on plasma emissivity calculated with the FLYCHK spectral tool [5]. This method is described in more detail in another contribution at this conference [6].

ARTIFICAL INTELLIGENCE ANALYSIS



As a complement to the atomic physics modelling of the 45-65 Å quasicontinuum, we wonder if a tomographic inversion of the measured spectra is possible. As a first step, we have studied the dependence between the observed spectral shape and the electron temperature. A principal component analysis (PCA) has evidenced the correlation between them. We then use a random forest algorithm to study in more detail the temperature predictibility. Provided we train the algorithm with measurements performed in similar discharges, the correlation is so good that the algorithm has a prediction capability within 100 eV in a broad temperature range (from 0.5 to at least 3.5 keV). It is even able to predict the electron temperature profile along a line of sight of the spectrometer with the same uncertainty. The next step is to investigate whether the spectrum at a single temperature can be built with the AI algorithm.

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