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ATOMIC CARBON COLLISIONAL – RADIATIVE MODEL FOR TOKAMAK PLASMA EDGE DIAGNOSTIC

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In a Tokamak, the region between the plasma core and the wall is characterized by strong free electron density (~ 10^{20} m^{-4}) and temperature (~ 10^{7} K m^{-1}) gradients [1]. Such plasma properties are very difficult to measure accurately. The Thomson scattering is a powerful mean [2] whose results worth to be confirmed by another kind of experimental technique. From this point of view, the Beam Emission Spectroscopy which has been successfully applied on fusion facilities at PISCES and TEXTOR [3] is a good candidate: an atomic beam produced at the wall of the machine is progressively excited when it crosses the plasma edge. The resulting radiative emission can be analysed and related to the local free electron properties by means of a Collisional-Radiative (CR) model.

In this work, a model for simulating the interaction between a typical Tokamak plasma edge and an atomic beam resulting from the laser-induced ablation of a carbon target is developed and some results are presented. The model is mainly based on the following assumptions:

1- the C atoms enter the plasma under weak density and low temperature conditions,
2- the properties of the plasma are not significantly modified by the carbon beam,
3- the contribution of the protons to the C excitation is negligible,
4- the C^+ ions are totally reflected by the local magnetic field,
5- the free electron density and temperature gradients are uniform,
6- the C emission lines are optically thin and collisions between C atoms are negligible,
7- the C^+ ions are only produced on the [He]$2s^2$2p ground state.

The C energy spectrum is taken from the NIST database [4]. 268 levels are involved in the calculation (see Table 1). The cross sections of the electron-induced transitions (excitation and ionization) are derived from the hydrogenlike approach developed by Drawin [5]. We plan to get more accurate values from using both COWAN's and HULLAC atomic structure codes developed at the Los Alamos and Aimé Cotton laboratories.

Table 1. Some among the 268 carbon levels involved in the present CR model (from NIST).

i	Configuration	Term	Energy (eV)	J
1	$[He]2s^22p^2$	3P	0.000000	0
2	$[He]2s^22p^2$	3P	0.002033	1
3	$[He]2s^22p^2$	3P	0.005381	2
8	$[He]2s^22p3s$	3P*	7.482772	1
9	$[He]2s^22p3s$	3P*	7.487795	2
10	$[He]2s^22p3s$	1P*	7.684766	1

Diffusion is a slow phenomenon as compared to the transport mechanism of the laser-ablated particles and the momentum transfer from the plasma edge species to the C atoms is negligible. Consequently, the velocity of the beam particles can be regarded as quasi-uniform. With D/Dt referring to the usual hydrodynamic derivative, we solve the balance equation for the carbon atoms in the excited level i, which reads under the simple form:

$$\frac{D\,[C(i)]}{D\,t} = \left(\frac{\partial\,[C(i)]}{\partial\,t}\right)_{\text{Coll.-Rad.}}$$

For instance, Figure 1 shows the spatial distribution of some C levels when the beam velocity, the electron density and temperature gradients are respectively fixed at: $v = 1$ km s^{-1}, $dn_e/dx = 2.4\ 10^{20}$ m^{-4} and $dT_e/dx = 2.5\ 10^7$ Km^{-1}. One observes that the penetration of the beam inside the plasmas is only limited to about 1 cm. The intensity and broadening of the C emission lines derived from our CR model could be directly compared to the experimental ones with the aim of validating our numerical approach.

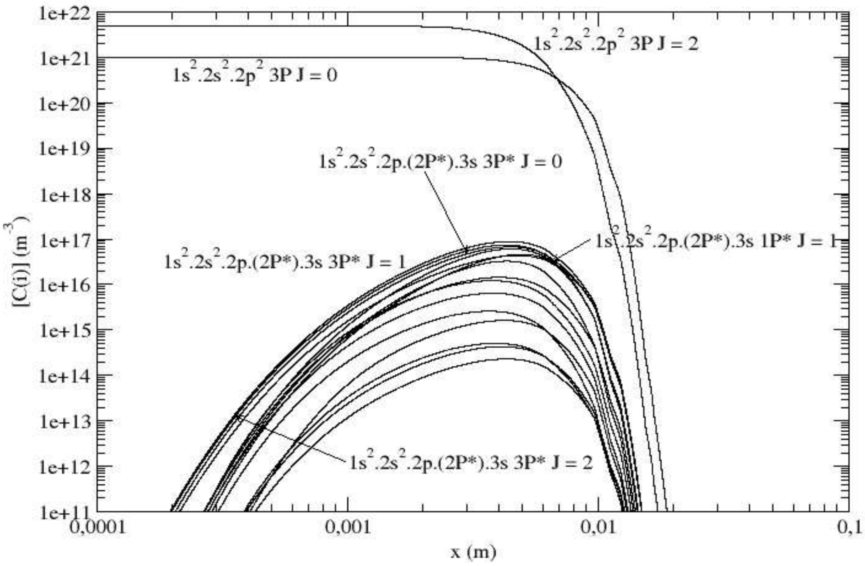

Fig. 1: Excited states distribution of C atoms in a typical Tokamak edge plasma.

Reference

[1] R.E.H. Clark, D.H. Reiter 2004 *Nuclear Fusion Research* (Springer Series Chemical Physics, Berlin)
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[3] O. Schmitz *et al.,* 2008 *Plasma Phys. Control. Fusion* **50** 115004
[4] NIST Database: http://physics.nist.gov/PhysRefData/contents.html
[5] Drawin H.W., DPh-PFC/SRFC EUR-CEA-FC-383 (1967)