SIMULATION OF THE VUV SPECTRA FROM THE REVERSED FIELD PINCH EXTRAP T2R

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During 2004, the common research work between *Atomic and Ionic Spectroscopy Group* with the National Institute for Laser, Plasma and Radiation Physics, (NILPRP), Bucharest, Romania, and *Atomic and Molecular Physics Group* with The Royal Institute of Technology, (KTH), Stockholm, Sweden, has been concentrated towards hydrogen, the continuum and the series limit, the recombination spectrum (the volume recombination)- and the accurate measurements of the fluxes which are derived from absolute intensities. Another path has been the investigation of the recombination and bremsstrahlung contribution to the total radiated power loss from the Extrap T2R plasma.

The main issue addressed through the present collaboration is the development of the methods of interfacing atomic modelling to integrated plasma modelling As fusion plasma science has evolved over the last half century, atomic modelling has had to evolve with fundamental and derived atomic data calculations to deliver cutting edge atomic modeling and analysis in key applied field, essentially plasma spectroscopy (macro task 3 –3.6). This is because the fusion plasma is neither at the low density or high density extremes. It displays huge temperatures and variations of temperature, and it is dynamic with substantial transport of atoms within in the plasma. The hydrogen continua and spectral line emission from high *n*-shells were considered in order to characterize the Reversed Field Pinch (RFP) plasma at Extrap T2R device, as an example. During spectroscopic analysis a consistent picture of the evolution of plasma parameters can be achieved on the basis of the relationship of the photon emission rate and the ionization or recombination flux. Based on the use of the Atomic Data Analysis Structure (ADAS) program package, the investigation of the relationship between the photon emission rate of the Balmer α line to the ionization or recombination fluxes has been conducted in order to evidence the existence of the net recombination volume and Balmer series limit.

1. Study of Hydrogen Balmer series emission as related to the effect of dynamic and static ion fields on population picture at the EXTRAP T2R plasma device.

- *Theoretical simulation*

Atom in plasma static ion field is assumed to lie in a constant Stark electric field produced by the almost stationary ions, which splits the degenerate levels. This is then further averaged over the ion field probability distribution function to produce a broadened spectrum. The static fields yield an ionisation lifetime. Dynamic fields created by ions moving inside

the Debye sphere around the neutral atom fit into the framework of collisional theory and may be treated as rate coefficients in population equations. It is an objective of this work to incorporate this consistently into the population picture and hence diagnose temperature and densities.

A special attention was paid to the electron density, n_e, dependence of the effective collisional ionization rate and the ionization flux and the electron temperature dependence of the photon emission rates and the recombination flux [1]. We demonstrated that in the Extrap T2R plasma the model suggests the relationship of type: $d\ n_e\ /\ dt \propto I_{H\alpha}$, where $I_{H\alpha}$, is the intensity of the Balmer alpha line. Theoretical work on the simulation of the Balmer spectrum for high series lines and at the continuum edge (λ = 3646 Å) as a diagnostic for electron temperature inside the plasma can be summarized as follows :

a) The use of Atomic Data Analysis Structure (ADAS) package to output atomic data. They were been included into the calculation of atomic population distribution and prediction of the Balmer spectrum for high series lines, and at the continuum edge; Opacity effects[2] have been taken into account.

b) A routine which integrates along a line of sight out of the plasma so that an emergent spectrum can be predicted; Simulated bremsstrahlung emission spectrum is given in the Figure 1.

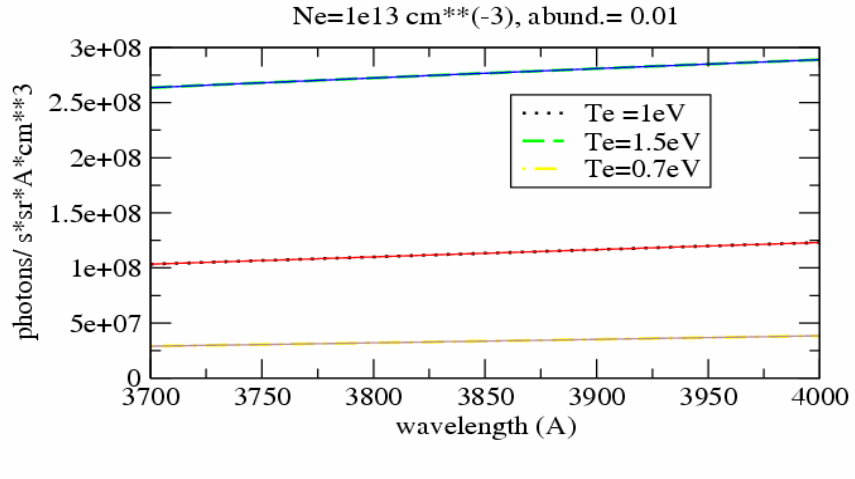

*Figure 1. Bremsstrahlung emission intensity (in photons/[sr*s*Å*cm^{-2}] units) of hydrogen atoms (abundances 0.01) as function of wavelength (in Å units) for given electron density, N_e, of 10^{13} cm^{-3} and different electron temperatures, T_e = 0.7, 1, 1.5 eV into the plasma.*

- *Experimental data for comparisons*

The Swedish collaborators have started seriously with the spectroscopy at T2R and to calibrate the instruments. Work on the interpretation of the hydrogen emission using ADAS has been focused checking the Hα/Hβ/Hγ ratios with the predictions. *It has not been observed limit of the Balmer series.* However, one interesting aspect that have been extracted from these experiments was how large a fraction of total radiative power comes from the hydrogen bremsstrahlung, how much of the continuum comes from recombination to various impurity ions present in the plasma.

2. Radiated power and impurity concentrations in the Extrap T2R reversed field pinch

The previously discussed results on the hydrogen contribution to the total radiative power loss have been included into the numerical study of the impurities concentration and radiation in the rebuilt Extrap-T2R device. The operated regime of interest has been limited to the medium plasma current with long flat top conditions (~85kA, up to 7ms) for optimized plasma measurements. The experimental setup consisted in the recently upgrade 8-cord bolometer system (now covering the inner and outer field side) and a vacuum ultraviolet (VUV) spectrometer. For the considered plasma conditions the radiated profile measured by the bolometric system exhibits a peaked shape that is in contrast to the results obtained in the RFX device. To analyse this particular shape and evaluate the impurity concentrations a 1D Onion Skin Collisional-Radiative model (OSCR) including charge exchange process and Bremsstrahlung emission has been developed. First OSCR simulations have shown that it is necessary to take into account the charge exchange process with neutral hydrogen to reproduce the observed peaked shape. Therefore, the neutral hydrogen density is computed with an adapted version of the recycling code EDCOLL (used in the Tore Supra tokamak). The Bremsstrahlung emission is estimated to contribute as about 5% of the total radiated power[3].

References:

[1] **Stancalie V., Rachlew E.,** "*Emission from hydrogen atoms as related to the modelling of the Extrap T2R plasma"* Paper Presented at the XXIII International Conference on Photonic, Electronic and Atomic Collisions, Stockholm, Sweden, July 23-29,2003.

[2] **Stancalie V., Rachlew E.,** "*Study of opacity effect on emission line at EXTRAP T2R RFP*", Physica Scr, 66 (2002) 444-448.

[3] **Corre Y., Rachlew E., Cecconello M., Gravestijn R. M., Hedqvist A., Loch S., Pégourié B., Schunke B., Stancalie V.,** "*Radiated power and impurity concentrations in the EXTRAP T2R reversed-field pinch*"" Physica Scripta 71 (2005), (in print).