SIMULATING THE OXYGEN EMISSION FROM ADITYA-U TOKAMAK USING VARIOUS SPECTROSCOPIC MODELS

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A multi-track spectrometer is used to capture the spatial profile of the visible spectral line of OV ion [1], while a VUV spectroscopy system equipped with a VUV survey spectrometer, operating in the 10-180 nm spectral range [2], is regularly utilized to monitor spectral emissions from various ionization stages of carbon, oxygen, and iron which are employed to find out the local plasma density and electron temperature in ADITYA-U tokamak. Although these lines (such as 650.024 nm and 646.614 nm) are readily observed, they are not utilized for diagnostic purposes. Moreover, the researchers did not pay much attention to estimate the cross sections and rate coefficients of these emission lines. In the present work, the cross-sections and rate coefficients for the electron-impact excitation process are calculated using the Flexible atomic code (FAC) [3], RDW1 [4], ADAS [5] and an analytical approach [6] to model the above experimentally measured line intensity ratio. The experimentally observed visible spectra for the typical discharge of ADITYA-U tokamak for O^{4+} ions are given in Figure 1. A similar type of observation was mentioned earlier by Lippmann et. al. [7], where they reported experimentally recorded brightness of the spectral lines at 650.024 nm and 646.614 nm in DIII-D tokamak plasma and estimated the same with a collisional radiative model based on HULLAC package [8]. However, one of the above-predicted wavelengths differs from the observed wavelength by 68 Angstorm.

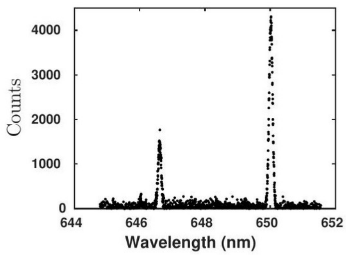

Fig.1: Experimental measurements of spectral lines 646.614 nm and 650.024 nm, respectively, for the typical discharge of ADITYA-U tokamak.

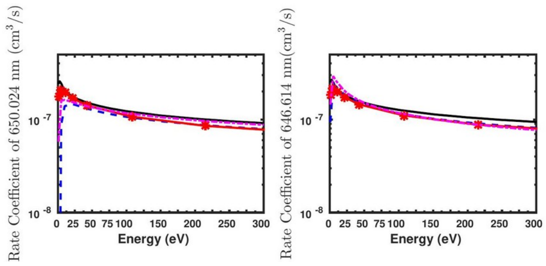

***Fig.2:** The black solid, blue-dashed, red solid with star and magenta dash-dot curves represent, excitation rate-coefficients from the FAC, RDW, ADAS and analytical calculations, respectively.*

The Flexible Atomic Code (FAC) is employed for calculating the atomic structure data, i.e., energies, radiative rates, and electron impact excitation cross section using the relativistic distorted wave approach. The FAC utilizes the modified multiconfigurational Dirac-Hartree-Fock-Slater method to simulate the above atomic structure data. The FAC is successfully installed and implemented for ADITY-U tokamak plasmas, which is also employed to model the emission spectra for various other machines [9,10]. In this study, the electron impact excitation cross sections for the transition from $1s^22p3d$ to $1s^22p3p$, i.e., $^3F^0_4$ - $^3D_3$ (650.024 nm) and $^3F^0_3$ - $^3D_2$ (646.614 nm), respectively, are simulated from the FAC code after considering required electronic configurations. The simulated energy levels from the FAC are closely agreed with the NIST [11] values within 5%. Moreover, the electron-impact excitation rate coefficients are also calculated using the Maxwellian electron energy probability distribution function to model the experimentally observed line intensity ratio. Various other approaches such as RDW1, ADAS, and an analytical method are also employed to compare the excitation rate coefficients from FAC. Figure 2 shows the electron-impact excitation rate coefficients for the transition lines

650.024 nm and 646.614 nm calculated from all of the above approaches. It showcases that the excitation rate coefficients from the above methods are in close agreement with 10% except near the threshold energy for the transition. It is also found that the estimated line intensity ratio obtained from the corona approximation deviates from the experimental line ratio, which is around 1.84 (see, Figure 1). Although, the radiative transition probabilities for the 650.024 nm and 646.614 nm lines are $1.11\text{x}10^{7}$ s^{-1} and $1.01\text{x}10^{7}$ s^{-1}, respectively, when we involve only the upper and the lower states. However, the possible radiative transition rates from the upper to many lower states are $2.31\text{x}10^{7}$ s^{-1} and $4.38\text{x}10^{7}$ s^{-1}, respectively. Earlier studies predicted that the lifetime of the $^{3}F^{0}_{4}$ state is two times more than that of the $^{3}F^{0}_{3}$ state [12]. Therefore, it can be concluded that a collisional radiative model is necessary to estimate the above intensity ratio. Further, the photon emissivity coefficients (PEC) are also generated utilizing ADAS-208. The ratio between these two PECs is calculated and plotted in Figure 3. The calculated ratio of the OV spectral lines agrees quite well with the measured ratio at electron density, $n_e = 1\text{x}10^{13}$ cm^{-3} [13]. The PEC ratio remains constant beyond 10 eV, indicating that it is independent of electron temperature. In addition to the above study, the line intensity ratio in VUV range line emissions from OIV (55.41 nm and 60.84 nm) and OV (62.97 nm and 76.05 nm) ions are also calculated to estimate the local electron temperature, which comes out to be around 45 eV. An indigenous collisional-radiative model is being developed, where the rate coefficients for excitation, ionization, and radiative recombination processes will be obtained from the FAC to estimate the PEC of the observed spectra in the ADITYA-U tokamak plasma to validate the experimental findings and predict impurity concentration in future fusion devices.

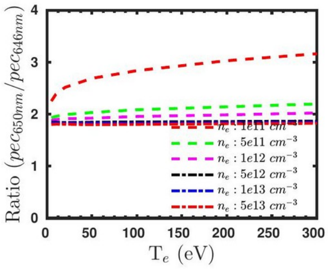

Fig.3 *Simulated PEC ratio of 650.024 nm and 646.614 nm from ADAS for various electron densities.*

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