#69

Estimation of argon impurity transport in Aditya-U Ohmic discharges using Be-like, B-like and Cl-like argon spectral line emissions

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Argon seeding in a tokamak has several benefits such as, achieving lower-H-mode thresholds [1, 2], reducing heatloads on plasma-periperals through radiative power dissipation at the plasma boundary [3] etc. Trace argon is also injected for diagnostic purposes [4, 5]. Nonetheless, argon accumulation in the core and its high radiation through line and continuum emissions result in confinement degradation and fuel dilution and it is an important concern for the present and future tokamaks such as ITER [3]. Therefore, it is important to understand argon impurity dynamics in fusion plasmas thereby controlling argon concentration and accumulation inside the plasma column.

Vaccuum Ultraviolet (VUV) and visible line emissions from partially ionized argon impurity ions are simultaneously observed in the Aditya-U [6] ohmically heated plasma with trace argon impurity injection ($\approx$ 1017 particles) during the current flat top phase of the discharge. These line emissions, observed using abolutely calibrated high resolution visible and VUV spectrometer systems are used to understand argon impurity dynamics in the plasma [7]. Argon transport coefficients (diffusivity and convective velocity) are calculated from the integrated use of these two spectroscopic diagnostics and the 1D impurity transport code STRAHL.

During the experiments, space resolved visible line emissions of Cl-like argon ions and line integrated VUV line emissions from Be-like and B-like argon ions have been observed. The Ar^+ line emissions in the visible range at 472.68 nm ($3p^4 4s^2 P_{3/2} - 3p^4 4p^2 D_{3/2}$), 473.59 nm ($3p^4 4s^4 P_{5/2} - 3p^4 4p^4 P_{3/2}$), 476.48 nm ($3p^4 4s^2 P_{1/2} - 3p^4 4p^2 P_{3/2}$), 480.60 nm ($3p^4 4s^4 P_{2/5} - 3p^4 4p^4 P_{2/5}$) and VUV emissions of Ar^{13+} at 18.79 nm ($2s^2 2p^2 P_{3/2} - 2s2p^{22} P_{3/2}$) and Ar^{14+} at 22.11 nm ($2s^{21} S_0 - 2s2p^1 P_1$) are identified using NIST database. From the experiments, radial emissivity profile of Ar^+ spectral emission and brightness ratio of Ar^{13+} and Ar^{14+} ions have been calculated simultaneously. In order to estimate the argon impurity transport coefficients, the experimental emissivity profile and brightness ratio need to be simultaneously compared with those simulated using the impurity transport code, STRAHL. Since the photon emissivity coefficeints (PEC), required to obtain the emissivty profiles of the observed transitions, are not directly available, they have been generated using NIST and ADAS databases. For all the observed transitions of Ar^+, Ar^{13+} and Ar^{14+} ions used in the study the appropriate fundamental data related to electron impact excitation rate coefficients are obtained from the ADAS database, by properly matching the energy levels between NIST and ADAS database. These data were then used in ADAS generalised collisional-radiative (GCR) data production routine which provided the required PECs for the range of electron density and temperature. The calculated PECs were then used in STRAHL code to simulate the emissivity profile of Ar^+ spectral emission and brightness ratio of Ar^{13+} and Ar^{14+} ions and compared with experimental values to estimate argon transport coefficients. Argon diffusivity $\approx 12\,\mathrm{m}^2/\mathrm{s}$ in the edge (ρ ¿ 0.85) and $\approx 0.3\mathrm{m}^2/\mathrm{s}$ in the core region have been observed. The diffusivity values in the edge and core are found to be higher than the neo-classical values, which suggests that the argon transport is mainly anomalous in the Aditya-U tokamak. Moreover, it has been observed that an inward pinch of $\approx$ 10 m/s is required to match the experimental and simulated data. The measured peaked profile of total argon density suggests impurity accumulation in these discharges. The detailed results on experimental measurements, calculation of PEC profiles and argon transport coefficients will be discussed in the paper.

References

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