Impurity Transport Study Based on Measurement of Visible Wavelength High-n Charge Exchange Transitions at W7-X

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Detailed studies of impurity transport are critical for the success of magnetic confinement fusion power plants since an uncontrolled accumulation of impurities could significantly degrade reactor performance. Here, we present a novel spectroscopy approach to investigate impurity transport by analyzing line-radiation following high-n Rydberg transitions.

While high n-Rydberg states of impurity ions are unlikely to be populated via impact excitation, they can be populated by charge exchange reactions along neutral beams in high temperature plasmas. Hence, localized radiation of highly ionized impurity ions, free of passive contributions, can be observed along neutral beams. At the W7-X stellarator experiment, several of these Rydberg transitions have been found in the wavelength range between 490 and 510 nm. The emission lines are agnostic to the impurity species and charge states Z=14, 21, 23, 25, 45, 47 have been observed following dedicated injections of either iron or tungsten ions.

The measurements have been enabled by a new high throughput, intensity calibrated CXRS system [1] which features a temporal resolution of 1 kHz and has been installed during the OP2 campaign of W7-X. First analysis results using forward modeling with pySTRAHL [2] embedded in a Bayesian framework demonstrate for the first time at W7-X, the simultaneous inference of both the impurity diffusion and convection profiles. Moreover, strong impurity diffusion and a clear inward convection of impurity ions is observed in the plasma center which can be used to validate predictions for impurity transport made by neoclassical and gyrokinetic codes.

References

[1] C. Swee et al 2022 Rev. Sci. Instrum. 93, 103523
[2] C. Swee et al 2022 Plasma Phys. Control. Fusion 64 015008

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