

2D measurements of impurity flows and line radiation in the W7-X scrape-off layer for attached and detached plasmas

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Characterizing the scrape-off layer (SOL) transport properties of Wendelstein 7-X (W7-X) is essential to assess the efficiency of its exhaust concept, the island divertor configuration. Insights into the SOL dynamics in attached and detached conditions can be gained by the measurement of particle flows. Investigations of impurity flow velocities and line radiation have been carried out with the Coherence Imaging Spectroscopy (CIS) diagnostic, featuring 2D spatially resolved measurements that led to the first direct detection of the 3D counter-streaming flow pattern of the W7-X SOL [1]. The impurity monitored by CIS is C^{2+} , selected via the C III transition line at 465 nm ($2s3p^3P^o \rightarrow 2s3s^3S$). Its line-emission intensity, integrated over the entire camera view, is observed to be linearly proportional to the total plasma radiated power in both attached and detached plasmas for non-seeded conditions. The related C^{2+} velocity exhibits a strong dependence on the electron density measured at the divertor, while the SOL input power has no direct influence on the velocity magnitude. In attached plasmas, both the velocity and the divertor density increase with increasing line-averaged density. The tendency reverses in the transition to and during detachment, in which both quantities decrease by at least a factor of 2 [2, 3]. The sharp drop in velocity, together with a rise in line-emission intensity, is reliably correlated to the achievement of the detached state and can therefore be used as one of its signatures [2]. Another distinctive feature of the measured C^{2+} radiation during the transition to detachment is the appearance of localized emission areas around the X-point regions of the island chain, as predicted by EMC3-Eirene simulations [4]. In the domain of the measurements, the impurity flow velocity appears to be well-coupled with the main ion one, thus implying the dominant role of impurity-main ion friction in the parallel impurity transport dynamics [5]. Using the C^{2+} impurity flow as a proxy for the bulk plasma one, the CIS measurement results are interpreted with the help of EMC3-Eirene simulations, but their major trends are already explainable with a simple 1D fluid model, based on the continuity equation and the SOL power balance. At the same time, EMC3-Eirene modelling is not able to entirely capture the measured tendencies in the CIS flow velocities, due to the incompleteness of the physical model currently used in the code. A key missing physics aspect is the $E \times B$ drift, which is shown to substantially influence the measured flows [6].

References

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