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Dependence of Up/Down Asymmetry of Tungsten Impurity Ions on Toroidal Rotation in EAST H-Mode Discharges

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The poloidal asymmetry of impurity ions has recently attracted considerable interest due to its strong effect on neoclassical radial impurity transport in core plasma. The in/out asymmetric distribution of tungsten (W) ions was observed in ASDEX upgrade [1] and JET [2] by tomographic inversion of two-dimensional soft x-ray (SXR) emissivity profiles. The result suggested an enhancement of inward neoclassical convection. Meanwhile, the up/down asymmetric distribution of argon (Ar) was observed in C-mod [3]. However, the up/down asymmetry on heavy impurities like tungsten have not yet been studied experimentally. In EAST that has been operated with the tungsten divertor since 2014, on the other hand, the up/down asymmetry have been observed for W^{27+}-W^{36+} ions for the first time in EAST H-mode discharges using high-performance space-resolved extreme ultraviolet (EUV) spectrometers [4]. The up/down asymmetric factor, $f_{asy}(=I_{u,max}/I_{d,max}-1)$, is strongly dependent on the toroidal rotation and is directly (inversely) proportional to toroidal rotation velocity V_{t0} with toroidal magnetic field B_t in a clockwise (counter-clockwise) direction from top to bottom. The V_{t0} can be modified by means of neutral beam injection (NBI) and impurity seeding. The proportional relation of f_{asy} is found to be stronger for W^{27+} ions, which locate outer plasma region compared to W^{32+} and W^{36+} ions. Furthermore, it is found that the core tungsten concentration is significantly proportional to this asymmetric factor, indicating a strong effect of the up/down asymmetry on tungsten transport. Based on extended neoclassical theory for the up/down asymmetry of impurity [5], dominant effects of V_{t0} on f_{asy}, the reversal of the proportional relation between f_{asy} and V_{t0} in a reversed direction of B_t, and the sign reversal of the f_{asy} at low V_{t0} observed in EAST can be qualitatively understood with the theoretical prediction. The experimental observation and study on the asymmetric distributions of tungsten ions can provide valuable insights on the control of high-Z impurities in EAST, ITER and future fusion reactors.

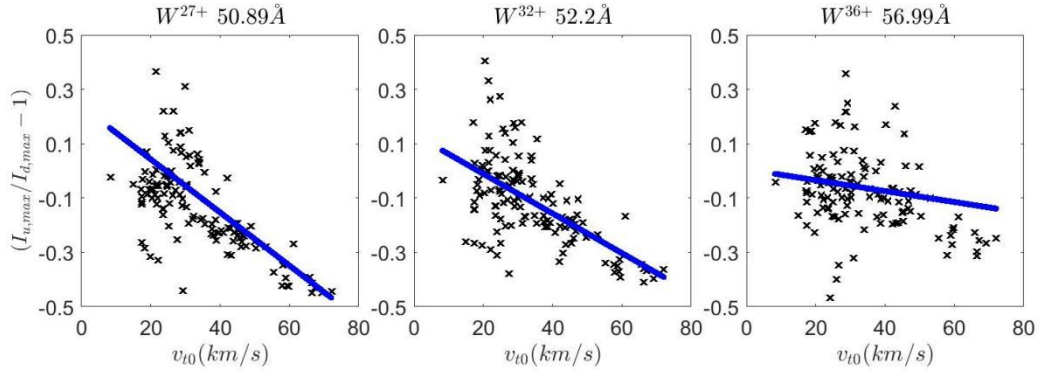

Fig. 1 Relation between up/down asymmetric factor, f_{asy}, and central toroidal rotation velocity, V_{t0}, for W^{27+}, W^{32+} and W^{36+} ions in counter-clockwise B_t. The f_{asy} for impurity ion with specific ionization state (e.g. W^{27+}) is defined as the ratio between two maximum values of chord-integrated line intensity above/below mid-plane ($I_{u,max}/I_{d,max}$-1). The blue line is obtained by linear regression.

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