# 2D distribution and up-down asymmetry in low-Z impurity radiation in Wendelstein 7-X

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The highly optimized Wendelstein 7-X (W7-X) stellarator has an inherent 3D magnetic field topology with fivefold symmetry. The island divertor concept uses magnetic island chains to separate the confined plasma region from the divertor targets, shielding the core plasma from direct penetration of impurities (mainly oxygen and carbon) from the plasma-wall interaction. The complexity of the 3D field structure makes it challenging to understand the impurity transport, which is essential for finding optimal operating windows with high performance in the core and high power dissipation in the SOL. In contrast to the initial limiter operation of W7-X in 2016, stable high-radiation scenario could now be achieved while operating with a divertor, irrespective of wall-conditioning (i.e. wall-boronization). The experiments demonstrated stable, "complete" power removal from the targets by low-Z impurity radiation, i.e. plasma detachment. However, the impurity radiation in W7-X usually exhibits an asymmetric up-down property, especially in high-density, high-radiation scenarios, which has been observed by bolometers monitoring the up-down symmetric triangular cross section. Recently, bolometer tomography has revealed the detailed radiation properties of the low Z impurities: 1) edge-localized 2D radiation patterns with clearly resolved magnetic island radiation structures, 2) an up-down asymmetry in the impurity radiation not captured by 3D edge plasma transport modeling, 3) reversal of the up-down asymmetry, when the direction of the toroidal magnetic field is reversed, 4) radiation condensation around certain X-points under high radiation and plasma detachment scenarios, 5) in deeply detached plasma, the poloidal position of the most intense emission can change and even cause a reversal of the up-down asymmetry.

Further analysis shows a poloidal variation of the emissivity in the outer confined plasma region with an asymmetry dependent on the field direction, which is also confirmed by the soft X-ray measurements. It is mainly due to highly charged ions (such as OVI) in the studied plasmas; they reside around the LCFS associated with helium-like ions, which are widely distributed in the outer confined plasma region and have a long lifetime. These helium-like ions are less affected by the impurity sources, and their asymmetries allow us to study the parallel transport of impurities. Our findings are: 1) the collisionality of the edge plasma and thus the friction force between main ions and impurities is sufficiently high to develop an asymmetry of impurities, as predicted by the neoclassical theory of parallel impurity transport. 2) The asymmetry reversal in the deeply detached plasma during discharge is due to the steeper density gradient and the variation of the radial electric field (measured by Doppler reflectometer), which change the thermodynamic forces acting on the impurities.

Experimental observations and detailed analyses are presented for representative plasmas in limiter and "standard" divertor configurations in experiments before and after boronization.