Impact of ICRF on the scrape-off layer and on plasma wall interactions: from present experiments to DEMO

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During the last decade, studies of the impact of ICRF (Ion Cyclotron Range of Frequencies) power on interactions with the scape-off layer plasma have been actively pursued on many experiments with metallic walls: in ASDEX Upgrade (AUG), in Alcator C-Mod and in JET-ILW. The studies of the impurity production in particular are relevant for the use of ICRF systems in fusion reactors. This contribution gives an overview of the recent progress.

ASDEX Upgrade experiments show that the impurity generation associated with the ICRF power can be drastically reduced by minimizing the RF currents on the plasma facing antenna frame elements. This approach was at first demonstrated by using the modified broad-limiter 2-strap antenna, then further developed with the 3-strap antenna concept where the RF image currents on the antenna frame are cancelled by optimizing power balance between the straps. The concept of the image current cancellation was successfully extended to a 4-strap antenna by using the Field-Aligned (FA) antenna in Alcator C-Mod, where the RF-enhanced potential measured on the magnetic field lines connected to the active antenna was eliminated by the proper power balance. The impurity sources remote to the FA antenna, which govern the total impurity influx in Alcator C-Mod, were also reduced. The RF image current cancellation technique is thus fairly robust and is applicable to other experiments.

In AUG and JET-ILW, the DC biasing of the plasma on the magnetic field lines by the RF-current carrying structures manifests itself in multiple SOL modifications. In the vicinity of the antennas, increased DC currents and enhanced sputtering at the limiters are observed (AUG). Further away on the field line connections to the antennas, increased parallel ion energies (AUG) and increased sputtering rates (AUG and JET-ILW) are measured. At the same time, the density profiles close to the antenna (in AUG) and on the field lines connected to it (in JET-ILW) are modified due to the imposed 3D DC-field and the consequently forming E×B convective cells. Several numerical tools build a basis for the description of the interactions, with prospects of becoming quantitative. The electromagnetic codes TOPICA and RAPLICASOL for near-field calculations, the nonlinear code SSWICH for the modelling of the slow wave propagation and sheath rectification in the SOL, as well as EMC3-Eirene (a 3D fluid edge plasma transport code with kinetic neutrals for calculations of the density modifications) have been successfully applied to describe the experimental behavior. The latter was also used to study the effect of the local gas injection close to ICRF antennas in AUG and JET-ILW to increase the antenna loading and to further reduce the impurity sources.

Experience and techniques developed in the recent studies can be used to optimize antenna design and to recommend operational recipes, to ensure the high-Z and high power compatibility of the ICRF system in the next-step machines, such as ITER and DEMO.