Exploration of Radiative Edge Cooling in the Island Divertor at Wendelstein 7-X

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Intrinsic and actively injected impurities are shown to directly impact on plasma edge conditions in correlation to the 3D magnetic structure of the scrape-off layer (SOL) at Wendelstein 7-X. The location of intrinsic impurities is directly correlated to the main strike line heat and particle fluxes. Therefore, active gas injection must be aligned with the island divertor geometry to be effective. The cooling capacity from dedicated injected gases is used to steer the heat flux to plasma facing components and also to manipulate the neutral fueling behavior. The results presented are an important first time exploration of the impact of radiative edge cooling by impurities on transport in the plasma SOL and at the core-edge interface.

The study encompasses a combination of results from a numerical analysis with the coupled 3D fluid plasma edge and kinetic neutral transport Monte-Carlo Code EMC3-EIRENE and experiments during the limiter startup campaign and the first island divertor campaign. In the startup configuration, the limiter positions and their poloidal extension resulted in a helical SOL consisting out of three types of separate helical flux bundles. These distinct magnetic flux tubes allowed a transport analysis based on simple SOL models and a heat flux characterization of power decay lengths $\lambda_{q\|}$ and peak heat flux values comparable to methods applied at tokamaks. Experiments with nitrogen (N_2) and neon (Ne) injection demonstrated an edge temperature reduction clearly correlated to edge radiation enhancement. The N_2 injection showed a fast response in which T_e recovered almost entirely after the injection was stopped. Ne featured higher recycling and terminated the discharge due to increased radiation causing radiative instabilities. These experimental results were analyzed with EMC3-EIRENE simulations. N_2 was modeled as a gas source neglecting recycling and, in contrast, Ne was sourced from the limiters to incorporate its properties as a fully recycling species.

Initial results from first island divertor experiments at W7-X show that core fueling and refuelling is probably prevented by island neutral screening effects as indicated by predictive modeling [1]. Here, radiative edge cooling is investigated for steering the neutral fueling by controlling the edge temperature. Initial explorations with EMC3-EIRENE indicate, that the location of the gas injection with respect to the island geometry matters. Experiments are commencing about changing the fueling and seeding locations from remote valves to specific SOL locations at the island O-point close to the mid-plane or directly in front of the divertor tiles near the main recycling and erosion zones. Results from fueling experiments aided by radiative edge cooling will be discussed. A focus of this work is the investigation of a correlation of local cooling features to the edge island geometry in the standard island divertor configurations. First, Ne was injected in discharges without using island control coils (Icc=0kA) and showed in response an enhancement of edge radition and correlated drop of divertor target heat fluxes. For Icc=2.5kA the absolute radition level reduces and a faster decay in response of the impurity radiation induced by Ne seeding was observed. These experiments were repeated with N_2. First results indicate a lower increase of edge radiation and fast drop of edge radiation in comparison to Ne seeded discharges. A systematic analysis of these experiments based on 3D numerical simulations with EMC3-EIRENE will be presented.

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