Plasma-Surface Interaction and Plasma-Edge Studies in Wendelstein 7-X Operating with Passively Cooled Graphite Divertor

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The stellarator Wendelstein 7-X (W7-X) restarted operation in 2017 with ten divertor modules made of inertially cooled graphite plasma-facing components PFCs [1]. The plasma exhaust concept and first wall properties are substantially different from those in the initial campaign which had limiters and explicitly avoided edge magnetic islands. The ten divertors now intercept an edge island chain. Additionally the inner vessel has been complemented by adding graphite PFCs to the already installed CuCrZr heat shields.

Before the initial divertor operation started, the vessel was baked up to 150°C, and glow discharges in helium (He) and hydrogen (H) were performed to condition the device. ECRH discharges were conducted in He in order to reduce the impurity and H content to acceptable values for steady and long pulse operation. The main impurities have been identified spectroscopically to be carbon and oxygen in the plasma-edge layer (~10%) whereas the post-plasma outgassing also includes methane, water, and carbon monoxide. H outgassing from the first wall components, operated at room temperature, largely determined the fueling, but much less prominently than in the initial limiter phase [2]. Conditions improved with increased deposition of plasma flux and heat to plasma-facing sides during plasma operation. A major part of the initial studies was devoted to symmetrisation of the power and particle load to the divertor modules with the aid of a small external field in order to correct 1/1 error fields and target module misalignment [3]. Indeed the footprint of particle and heat load was successfully measured with a multitude of edge diagnostics including interference filtered cameras, infrared cameras, divertor spectroscopy, and sets of Langmuir probes embedded in the divertor PFCs. Typical heat fluxes achieved so far are up to 5 MWm^{-2} and particle fluxes in the range of a few $10^{23}H^{+}s^{-1}m^{-2}$ at the strike line distributed on the horizontal or vertical target. The edge topology at W7-X depends strongly on the selected magnetic configuration, i.e. due to different island chains responsible for the divertor function. Indeed divertor detachment associated with low electron temperature and high density has been observed. The reduction in the emission of CII and CIII light in the divertor suggests a strong reduction of the carbon source with higher fueling which is consistent with a reduction of the physical sputtering, whereas the chemical sputtering still remains. Detailed analysis of the recycling and radiation distribution in the divertor and associated modelling with EMC3-EIRENE is progressing [4] and results will be presented,

The global material migration from main chamber locations such as graphite tiles will be studied by dedicated post-mortem analysis of extracted plasma-facing components with markers after the initial campaign, i.e. in early 2018, and will be compared with modelling predictions. In addition dedicated plasmas with tracer injection are foreseen to describe and quantify the transport from the outer midplane to the divertor target plates. Indicating also the remote areas where layers will be build-up in time. These studies will aid in predicting the behavior in longer pulses in W7-X and the expected fuel retention levels by implanted and co-deposited fuel as well as point to areas where cleaning activities might be required.

[1] T. Sunn Pedersen et al. (2017) presented at the ISHW conference Kyoto
[2] T. Wauters et al. (2017) private communication
[3] P. Drewelow et al. (2018) to be presented as inv. oral at the PSI conference Princeton
[4] F. Effenberg et al. (2018) to be presented as contr. oral at the PSI conference Princeton