Toward steady-state divertor operation of Wendelstein 7-X
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The magnetic field structure of the Wendelstein 7-X (W7-X) stellarator inherently offers a divertor geometry. This is formed by a chain of natural magnetic islands residing at flux surfaces with low-order rational values of the rotational transform. The engineering task was to design the target plates such that the islands are intersected far from the plasma centre, that they can sustain the resulting load of 10 MW heating power under stationary conditions, and that they are compatible with different magnetic configurations, permitted by the versatile magnet system of W7-X.

This is achieved by an open divertor which consists of ten units, following the fivefold toroidal and the up-down stellarator symmetry of the device. The divertor units are located along the narrow sides of the elongated plasma cross-section, where the geometric distance between plasma centre and plasma edge is maximum. The surface of the target plates is adapted to the shape of the flux surfaces, such that the magnetic field lines meet the target surface under angles below $3^\circ$ in the areas with highest heat flux, thus limiting the effective power load to the targets to the specified value of 10 MW/m$^2$.

The High Heat Flux (HHF) divertor constructed for steady-state operation of W7-X consists of individual target elements, each of which is made from CFC tiles bonded to a water-cooled CuCrZr heat sink. Extensive tests were performed to demonstrate that these target elements satisfy the thermal load requirements. Although this design is capable to take the specified steady-state power loads, it is sensitive to thermal overloading, which might occur due to toroidal or up-down asymmetries. Infrared thermography will therefore be employed for a continuous surveillance. Before installation of this HHF divertor, W7-X will be operated for approximately one year with an adiabatically loaded Test Divertor Unit (TDU), which is built from thicker fine grain graphite elements with the same surface shape as the HHF divertor. In this operation phase (OP1.2), the energy per plasma pulse will be limited to $\sim 80$ MJ (e.g., 10 s at 8 MW heating power), and models of divertor heat load patterns can be verified on this temporary structure before installing the HHF divertor.

Beyond the measurement of asymmetries in the divertor heat load patterns, this operation phase will serve for a first exploration of divertor physics. Unlike a tokamak divertor, the connection lengths parallel to the magnetic field between the stagnation point and the target can reach several 100 m in the island divertor of a low shear device, in spite of the short geometric distance between last closed magnetic surface and target. The mechanism which can cause plasma detachment in an island divertor will be discussed. Furthermore, the investigation of particle exhaust and density control will constitute important parts of the OP1.2 divertor physics programme.