Core Diagnostics for WENDELSTEIN 7-X steady-state operation until 18 GJ

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For its second operational phase OP2 W7-X will be equipped with a fully cooled carbon fibre composite divertor developed for steady state operation. Successive campaigns will raise the injected energy per experiment to 18 GJ, corresponding to the project goal of a discharge duration up to 1800s at 10 MW. Interlaced high-performance phases with up to 30 MW (ECRH+NBI) are limited to 10s by the present technological conditions of NBI. A sufficient beta is required to prove the success of the W7-X optimization for reduced neoclassical transport, improved fast particle confinement and reduced Shafranov shift, which all come with increasing beta. In a stellarator, with inherently no current related Greenwald density limit, high-beta can be realized on a high-density path, which increases the electron-ion coupling hence the ion heating, reduces turbulent transport by reduced T_e/T_i , reduces neoclassical core transport in the 1/ν regime where the diffusivity is $D_{1/\nu}{\sim}T^{7/2}/n$, and reduces fast ion losses to the wall. Hence W7-X explores a high-density scenario up to densities ~1.5 10^{20} m^{-3} that integrates the reactor relevant beta in the core with detachment in the divertor. Continuous heating beyond X2 cut-off is achieved by O2 ECRH, which requires Te above the level of 2-3 keV for sufficient absorption. Peaked density profiles turned out to be a necessary ingredient to overcome ITG turbulence which otherwise limits Ti gradients. Hence, a careful mixture of heating schemes and profile shaping measures will be necessary to balance a reduction of energy transport towards its neoclassical level in a large fraction of the core while keeping sufficient turbulent particle- and impurity transport to avoid accumulation and maintain the control on the density profile.

This contribution provides an overview and gives examples of core diagnostics, as they are required for steady state high-density operation with a divertor and profile control. The inferred profiles then address the stellarator optimization. A particular task is the characterization of fast ion slowing down and -losses, which in a classical stellarator reactor could result in unacceptable wall loads and ultimately are deleterious for the heating efficiency. The dissipated energy 10MW·1800s impacts on the technical diagnostic realization via energy loads to in-vessel components and requires adequate data acquisition and control systems. In contrast, the variability of the magnetic configuration - and ultimately the selection of a candidate configuration for an integrated high-performance divertor scenario - does not have a severe effect on the core diagnostic design.