Progress in the operation of the Wendelstein 7-X stellarator

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The magnetic field of the optimized superconducting stellarator Wendelstein 7-X (major radius 5.5m, minor radius 0.5m, 30m^3 plasma volume) is produced by external coils only without the need of driven net currents in the plasma. This enables the device for long-pulse high performance operation exceeding by far typical time constants for achieving stationary conditions with respect to the evolution of thermal load on inboard tiles, transport processes and intrinsic internal currents. After the very first commissioning phase without divertors, W7-X restarted operation after the assembly of a graphite heat shield and 10 inertially cooled island divertor modules. Repetitive glow discharge procedures, the utilization of pulse trains of ECRH cleaning discharges in helium as well as wall conditioning by boronization reveal beneficial effect on the density and radiation control. Hence, plasma pulses in hydrogen of 31s flat-top phase with 5MW O2 ECRH heating at feedback controlled densities of 1.1 x 10^{20} m^{-3} under full detachment were possible to be maintained. During the detachment phase the heat loads onto the divertors were reduced by more than a factor 10. Applying additional repetitive pellet injection, densities up to 1.4 x 10^{20} m^{-3} were transiently established with improved ion/electron coupling leading to $T_e/T_i \sim 1$. In these plasmas a triple product of $nT\tau_E$ = 6.4 x 10^{19} keVs/m^3 had been achieved at a density of 8 x 10^{19} m^{-3}, a temperature of 3.4 keV and a peak energy of 1.1 MJ. Generally, in spite of neoclassical predictions, relatively small impurity transport times in the order of 100ms and no accumulative trends were observed so far for ECRH heating powers > 1MW. However, there are indications for long impurity confinement at low ECRH heating powers (<1MW) and in NBI-heated plasmas. In order to exclude impurity radiation losses from being a show-stopper for achieving high performance long-pulse discharges, the detailed study of the impurity transport character in W7-X and the exploration of the operational space of W7-X with respect to favourable regimes not afflicted by impurity accumulation is demanding. Impurity transport has been investigated by analysis of impurity tracer injections using laser blow-of technique and tracer-encapsulated solid state pellet (TESPEL) injection. Strong anomalous transport had been identified to dominate the impurity behavior. The underlying mechanisms are subject of present investigations.