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Overview of first Wendelstein 7-X high-performance operation with island divertor

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The optimized superconducting stellarator device Wendelstein 7-X restarted operation after the assembly of a graphite heat shield and an inertially cooled island divertor. This paper reports on results from the first highperformance plasma operation. Plasma densities of $1 - 4 \cdot 10^{19} \,\mathrm{m^{-3}}$ with electron temperature $5 - 10 \,\mathrm{keV}$ were routinely achieved with hydrogen gas fuelling, eventually terminated by a radiative collapse. Up to $1.4\cdot 10^{20}\,\mathrm{m^{-3}}$ plasma density was reached with repetitive hydrogen pellet injection. Here, the ions are indirectly heated, and at a density of $8 \cdot 10^{19} \,\mathrm{m}^{-3}$ temperatures $T_e \simeq T_i = 3.4 \,\mathrm{keV}$ were accomplished, which corresponds to $nT\tau_E = 6.4 \cdot 10^{19} \text{ keVs/m}$ with peak diamagnetic energy 1.1 MJ. Stable 25 s long-pulse helium discharges with 2-3 MW ECRH power and up to 75 MJ injected energy were created routinely for equilibrium and divertor load studies, with plasma densities around $5\cdot10^{19}\,\mathrm{m^{-3}}$ and $5\,\mathrm{keV}$ electron temperature. The divertor heat loads remained far below the limits. The O/C impurity concentration ratio has decreased in comparison to the previous limiter operation and no intrinsic impurity accumulation along with high edge radiation were observed in stationary plasmas. During pellet-fuelled hydrogen discharges, full detachment was observed with divertor target heat flux reduction by more than $\times 10$. Both X2 and O2 mode ECRH schemes were applied and electron cyclotron current drive (ECCD) experiments were conducted. During co-ECCD injection experiments with axial currents up to 13 kA, frequent fast crashes were observed mainly in the core electron temperature, suggesting a fast magnetic reconnection mechanism. The radial electric field measured with (Doppler) and correlation reflectometry changes sign at the plasma edge from +10...+20 kV/m to -10...-5 kV/m, fairly independent of discharge parameters and heating power. Edge and scrape-off layer turbulence was measured with both Langmuir probes and reflectometer diagnostics. Core turbulence was measured with a phase contrast imaging diagnostic and different levels of broad band turbulence as well as coherent Alfvén mode activity were observed.

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