Initial Results of the First Wendelstein 7-X Island Divertor Experiments

P. Drewelow, A. Ali, J. Baldzuhn, C. Biedermann, S. Brezinsek[a], K.J. Brunner, A. Card, O. Ford, Y. Gao[a], K.C. Hammond, D. Hartman, M. Hirsch, M.W. Jakubowski, J. Knauer, G. Kocsis[b], R. König, P. Kornejew, T. Kremeyer[c], M. Krychowiak, V. Moncada[d], H. Niemann, U. Neuner, M. Otte, F. Pisano[e], K. Rahbarnia, J. Schilling, T. Schröder, M. Sleczka[f], A. Puig Sitjes, T. Szepesi[b], H. Thomsen, V. Winters[c], G. Wurden, L. Vano, D. Zhang and W7-X team

Max-Planck Institut für Plasmaphysik, EURATOM Association, 17941 Greifswald, Germany
[a] IEK 4, Forschungszentrum Jülich GmbH, EURATOM Association, 52425 Jülich, Germany
[b] Wigner Research Centre for Physics, Institute for Particle and Nuclear Physics, EURATOM Association, PO Box 49, H-1525 Budapest-114, Hungary
[c] Department for Engineering Physics, University of Wisconsin - Madison, WI 53706, USA
[d] ThermaDIAG, 100 Impasse des Houllires, ZA Le Pontet, F-13590 Meyreuil, France
[e]University of Cagliari, Piazza d'Armi, 09126 Cagliari, Italy
[f]Institute of Physics, University of Szczecin, Wielkopolska 15, 70-451 Szczecin, Poland

Contact: peter.drewelow@ipp.mpg.de

After a successful initial plasma operation phase with limiter configuration [1], the stellarator Wendelstein 7-X was upgraded with a pumped, inertially cooled island divertor. It consists of two divertor units in five toroidally periodic modules that are made of carbon and radially intersect the outer half of a large edge magnetic island chain. The divertor operation enabled plasma discharges for up to 20s with a plasma energy of up to 839kJ, 200ms energy confinement time and a line averaged density of $1.1x10^{20}$ m^{-3}. The edge plasma, typically T_e = 20 to 50 eV, is strongly influenced by gas recycling at the divertor, impurity generation (mainly carbon) and by the edge magnetic topology. The results of a first systematic study of these divertor properties in different magnetic configurations are presented in this contribution. Divertor heat loads were derived from infrared thermography on all ten divertor elements. It confirms that the designed divertor surface allows a symmetric distribution of power loads of up to 10 MW/m². Various magnetic configurations can be accessed by the modular magnetic field coil system of Wendelstein 7-X. A change of the edge rotational transform ι results in different edge islands intersecting the divertor with rather different strike line patterns. The compensation of a residual n/m = 1/1 magnetic perturbation mode with an external coil set is necessary to allow for safe operation of the future next-stage divertor, which will incorporate active water cooling. The dependency of different plasma fueling scenarios on the fuel injection location (gas puffing or pellet injection) and edge density and temperature conditions was investigated. Fast visible cameras allowed, for example, the tracing of fueling pellets paths and the characterization of their penetration depth. Since core fueling to higher densities proved to be challenging, injections of Ne or N_2 were used to lower the edge plasma temperature and allow better penetration of neutral gas. Impurity flows could be investigated with edge spectroscopy channels as well as a camera system with filters of hydrogen and carbon lines. The ratio between H_α and H_γ line radiation revealed high recycling divertor regimes. This, in combination with vanishing heat fluxes as seen by infrared thermography and divertor thermocouples, hints at a first successful partial detachment. Radiative collapses in high density operation were investigated in their relation to impurity generation and inward transport, based on the carbon line emission pattern.

[1] T. Klinger, et al., Plasma Physics and Controlled Fusion **59** (2017), 014018