Impurities in long-pulse operation of W7-X

M. Kubkowska[1], M. Jakubowski[2], M. Krychowiak[2], A. Dinklage[2], M. Gruca[1], S. Jablonski[1], L. Syrocki[1], B. Buttenschoen[2], F.Reimold[2], Y. Gao[2], G. Fuchert[2], S. Lazerson[2], D. Naujoks[2], U. Neuner[2], O. Grulke[2], V. Winters[2], D. Zhang[2] and the W7-X team

[1]*Institute of Plasma Physics and Laser Microfusion, Warsaw, Poland*

[2]*Max-Planck-Institut für Plasmaphysik, Greifswald, Germany*

The Wendelstein 7-X (W7-X) wants to demonstrate an access of HELIAS-line of stellarators to high power and high performance at steady-state conditions. Such a scenario makes a stellarator an attractive candidate for a fusion reactor due to lower economical cost of a power plant operated continuously. Therefore, a number of experiments have been performed at the W7-X in order to demonstrate the long pulse operation.

During the W7-X operational phase OP1.2, which took place in 2017-2018, 100 s discharge with the attached divertor plasmas was achieved while detached conditions were achieved for about 27 s. Performed experiments showed that a robust detachment scenario allows to reduce the peak heat flux by almost an order of magnitude and no significant increase of impurity concentration was observed (with $Z_{\mathrm{eff}} < 1.5$) [1,2]. The length of the pulses were limited by the thermal limits of inertially cooled plasma-facing components.

In the operational phase OP2.1 with all plasma facing components (including new CFC divertor) actively water-cooled, the long pulse could be significantly prolonged. The longest attached discharge lasted eight minutes reaching 1.3 GJ energy throughput. In this experiment attached plasma was heated by averaged 2.7 MW of ECRH. The longest detachment program in OP2.1 was obtained with feed-forward Ne seeding, which allowed to remain the peak heat flux at the very low level, almost everywhere below 0.5 MW/m^2. As a consequence, no significant increase of impurity concentration occurs with the cooler plasma boundary, and the Z_{eff} stayed below 2. The spectroscopic observation confirms that there is no Ne accumulation in the plasma core, which is an important prerequisite for steady-state high power plasmas.

[1] M. Jakubowski et al. Nuclear Fusion **61** (2021) 106003

[2] M. Krychowiak et al. Nuclear Materials and Energy **34** (2023) 101363