Performance of the ECRH system of Wendelstein 7-X with regard to long pulse operation and high performance plasmas in the campaign OP2.1

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A main goal of the superconducting stellarator Wendelstein 7-X (W7-X) is to demonstrate steady state plasma operation at reactor relevant plasma parameters in discharges with a length of up to 30 minutes. For this purpose, W7-X is equipped with a steady state capable 140 GHz electron cyclotron heating (ECRH) system with an installed power of currently 8.3 MW. However, the installation of the actively cooled divertor of W7-X was not completed until the end of 2021, so that the approach to long pulse operation started end of 2022 with the operational phase 2 (OP2). In addition, the ECRH beam duct with its fully quasi optical transmission line was equipped in the last years with an air conditioning system to reduce the risk of arcing at high power and increase the reliability for long pulse operation.

In the first campaign OP2.1, which ended march 2023, the ECRH system was used to demonstrate discharges with a length of up to 8 minutes and more than 1 GJ injected energy into the W7-X torus. In these first long pulse tests, possible problems with the cooling as well as the control and reliability of the gyrotrons should be identified. For this reason, the injected power was limited to about 3 MW in attached plasmas and 5 MW in detached plasmas. Further progress was made on the development of high performance plasmas. The fuelling capabilities of the Neutral Beam Injection (NBI) was used to generate peaked density profiles and the reintroduction of ECRH leads to drastic increase of the central electron temperature with full coupling to the ions. Central beta values of more than 3 % were demonstrated with a confined energy of more than 1 GJ. Here, the triple beampath O2 heating scenario turns out as a key tool for operating W7-X at high beta values. To achieve even higher beta values and demonstrate the optimization criteria of W7-X, the installed ECRH power at W7-X will be doubled in the coming years. For this purpose, the number of gyrotrons will be increased from 10 to 12 and the power per unit from 0.9 MW to about 1.5 MW.