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The ECRH-Power Upgrade at the Wendelstein 7-X Stellarator

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The existing ECRH system at W7-X consists of 10 gyrotrons, with output power levels ranging from 0.6 MW up to 1.0 MW each, quasi-optical transmission lines and microwave launchers at the plasma vessel. The overall transmission efficiency of the fundamental Gaussian mode is estimated to be approx. 94 %. The ECRH system is commissioned for a max. pulse length of 1800 s at full power.
Compared to other large fusion experiments, W7-X has a relatively low power-to-volume ratio. However high heating power is particularly necessary for achieving high plasma beta values, where the improved confinement of fast ions, one of the optimization criteria of W7-X, can be examined. In addition, with higher heating power, one expects the achievement of improved confinement regimes, such as the H-mode. It is therefore necessary to expand the ECRH systems in several consecutive steps. It is planned to increase the number of gyrotron positions from 10 to 12 and at the same time to evolve the gyrotron output power in several development steps from 1 MW to nominal 1.5 MW and, finally, up to 2 MW. In a first step, the 11th position was fully equipped and a very first 1.5 MW gyrotron was developed at KIT and manufactured at Thales, France [1]. This 1.5 MW W7-X TH1507U gyrotron is a direct evolution of the 1 MW W7-X TH1507 gyrotron. In the second step, 3 more gyrotrons of the 1.5 MW class are to be ordered, with some of their critical components already designed towards even higher output power. In a final third step, a new 2 MW prototype is to be designed, built and tested. It is to be followed by 3 more 2 MW gyrotrons, so that the ECRH facility will finally be equipped with 3 times 4 gyrotrons each of the 1 MW, 1.5 MW and 2 MW class. At the same time, the transmission lines will also be upgraded for 2 MW operation. Here, the atmospheric transmission was considerably improved by a new powerful air drying system already. Furthermore, the minimum beam waist was enlarged in the critical areas of the new 2 transmission lines to reduce the risk of arcs. A special effort is also made to improve the reliability of the system by the fast control system. For operation at maximum heating power at W7-X, it is also necessary to operate simultaneously with the NBI heating. However, both heating systems must share the same high-voltage supply with 12 modules. Therefore an operation scenario of 2 gyrotrons on one high-voltage module is developed, so that parallel operation of 12 gyrotrons and 4 NBI sources is possible.

References

[1] K. A. Avramidis et al., Fusion Engineering and Design 164 (2021) 112173

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