Considerations for the Operation of a 140 GHz 1 MW Gyrotron at 175 GHz for CTS Plasma Diagnostics at W7-X

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ABSTRACT

Collective Thomson scattering (CTS) diagnostic allows measurements of ion temperature, fast ion velocity distribution function, plasma drift velocity, fuel ion ratio, etc. The CTS diagnostic for ion temperature measurements was installed and commissioned on the Wendelstein 7-X stellarator (W7-X) [1]. For this purpose, a 140 GHz gyrotron of the Electron Cyclotron Resonance Heating (ECRH) system is used as source for the probing beam. However, measurements in the plasma core suffer at this frequency from the absorption of the electromagnetic wave and from the high electron cyclotron emission background, which jeopardizes signal-to-noise ratio. For CTS measurements in the plasma core, it is therefore necessary to operate the gyrotron at a different frequency. Given that the refraction of the electromagnetic wave in the plasma increases with decreasing frequency of the wave, the gyrotron should operate at a frequency higher than 140 GHz.

Frequency change of an existing gyrotron at W7-X is not a straightforward procedure since the gyrotron and its subcomponents were developed and optimized for 140 GHz. Different frequencies that can leave the gyrotron are defined by the thickness of the diamond output window. For CTS purposes, the next higher frequency at which the output window is transparent is 175 GHz. The change to another frequency also implies the change of the cavity mode. Several candidate modes with a cut-off frequency close to 175 GHz and a caustic radius close to that of the nominal $TE_{28,8}$ mode were identified. The operation of these candidate modes was investigated in the three main components of the gyrotron: the quasi-optical system using the in-house developed code *KarLESSS* [2], the electron gun using the electron optics code *Ariadne* [3], and the cavity using the multimode code *EURIDICE* [4]. In the simulations, it is concluded that the $TE_{34,10}$ mode is the most suitable cavity mode at 175 GHz. With the $TE_{34,10}$ mode, a generated power in the cavity in the order of 650 kW in short-pulse operation and 550 kW in long-pulse operation is achieved with a beam current of 40 A and a beam voltage of 79 kV, similar to the nominal gyrotron operating parameters. The mode frequency is 173.9 GHz, which results in a 0.84 % reflection of the RF beam at the output window, whereas the Gaussian mode content of the RF beam is 87 %.

References

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