Extending the Physics Studies by ECE on ITER

I. Introduction

The Electron Cyclotron Emission (ECE) diagnostic provides essential information for plasma operation and for establishing performance characteristics in ITER. The baseline ECE system on ITER provides measurements of both the X- and O-mode radiation in the frequency range from 70 GHz up to 1 THz along two lines-of-sight, perpendicular and oblique at about 10 degrees, in the equatorial port. The system as planned meets the ITER measurement requirements. Nevertheless, there are several other mm-wave diagnostics in ITER, such as HFS, LFS and plasma position reflectometry, as well as Collective Thomson scattering system, whose transmission lines allow, in principle, additional measurements of ECE and/or additional redundancy for parts of the ECE spectrum with upgrades of their back-ends, improvements in filtering and/or additional receivers. A discussion of whether and how precisely to extend the physics from ECE measurements is given here.

II. Baseline ECE in ITER

- Diagnostic integration challenges
- Harmonics overlap
- Relativistic broadening restricting radial region of observation
- Calibration: absolute; hot sources
- Limitation: additional losses above Bragg scattering frequency at frequencies
- Calibration: possible but occasional (during shutdown only)
- In-vessel waveguide size: 20x12 mm, copper-coated inner surface
- Frequency range: X-mode, 10 – 98 GHz, O-mode, 15 – 155 GHz for LFS
- 4 pairs; in-vessel waveguides, antennas at the midplane at the HFS
- Calibration: possible (during shutdown) or cross-calibration
- Physics: a possibility for the restricted Te-profile measurements for the HFS of the tokamak are not affected by the absorption.

III. Restrictions for ECE on ITER

- Relative broadbanding restricting radial region of observation
- Harmonics overlap
- ECH stray radiation
- Diagnostic integration challenges

IV. Other diagnostics capable to measure ECE

- The baseline ECE system as planned meets the ITER measurement requirements. The advantages of the main ECE lines are:
- They are absolutely calibrated: they are O-X conversion optimized; they are stable in all bands; they have minimum parasitic signals, such as reflectometry leaks and ECH
- The extra transmission lines discussed here are almost by definition worse, so they can only be used to supplement the (solid) main measurements. The discussion here is mainly focused on the assessment of the various transmission lines of other microwave diagnostic which may expand the physics programme during ITER operation and deliver some additional knowledge in our understanding of the processes in the plasma, and not on the scope of each of these diagnostics.

V. HFS Reflectometry for ECE measurements

- Located in Equatorial Port 11; 6 pairs (12 waveguides); bistatic
- Frequency range: 15 – 220 GHz enabled for reflectometry; any polarization; up to 350 GHz for ECE detection
- Waveguides: copper-coated surface
- Z-range: 520 – 660 mm for different scenarios - covered
- Transmission line losses in the frequency range from 70 to 220 GHz: 15 to 25 dB
- Calibration: possible (during shutdown) or cross-calibration
- Physics: a possibility for the restricted Te-profile measurement for 1st harmonic O-mode and 2nd harmonic X-mode ECE; some redundancy for the NTM amplitude measurement; poloidal velocity measurement for MHD and turbulence

VI. LFS Reflectometry for ECE measurements

- Located in Equatorial Port 12; consists of the high-power launcher (from 60 GHz gyrotron, 2 MW delivered to the plasma) and receiver (mirrors-horns arrangement)
- Diagnostic receiver can allow redundant measurement of ECE when confined ion velocity distribution study programme is not running
- Physics: a possibility for the restricted Te-profile measurements within the transmission line capabilities (subject to study); redundancy for the NTM amplitude measurement

VII. Plasma Position Reflectometry for ECE

- Located in-vessel (as HFS-R), in the Upper and Equatorial Port plugs
- Frequency range for reflectometry: 15 – 60 GHz; higher frequencies could be enabled thanks to the waveguide performance
- Waveguides: similar to the HFS Reflectometry ones
- Transmission line losses: ~35 dB (1 THz)
- Limitation: additional losses above Bragg scattering frequency at 350 GHz
- Calibration: possible but occasional (during shutdown only)
- Physics: simultaneous monitoring of the ECE from HFS and LFS

VIII. Collective Thomson Scattering

- Located in Equatorial Port 12; consists of the high-power launcher transmission line (from 60 GHz gyrotron, 2 MW delivered to the plasma) and receiver (mirrors-horns arrangement)
- Diagnostic receiver can allow redundant measurement of ECE when confined ion velocity distribution study programme is not running
- Physics: a possibility for the restricted Te-profile measurements within the transmission line capabilities (subject to study); redundancy for the NTM amplitude measurement

Summary

Several microwave diagnostics in ITER can be used for parts of ECE measurements to enlarge the physics studies. The main driver for the reliable ECE measurement is the transmission line performance; depending on the type of the waveguide or front-end used in one or another diagnostic, some limitations to the observable range of frequencies is obvious. The transmission lines discussed here will allow access to the 1st harmonic O-mode and the 2nd harmonic X-mode in ITER, thus enabling a possibility for some back-end electron temperature profile and NTM temperature amplitude measurements. The latter can also be achieved by implementation of the in-line ECE system in the ECH Upper Launcher; it would give fast and reliable tool to track down and suppress the NTM in ITER before it reaches its critical size.

The views and opinions expressed here do not necessarily reflect those of the ITER Organization.