§1. Polarisation of the ECE Spectrum in LHD

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Electron Cyclotron Emission (ECE) can be used to determine the electron temperature profile in magnetised plasmas. For tokamak plasmas, the analysis of ECE spectra is relatively straightforward. However, in a heliotron stellerator, the magnetic configuration complicates the analyses of the emission spectra. The magnetic field is a non-monotonous function of the radius. Hence, ECE with equal frequencies are emitted from different positions in the plasma. Furthermore, the field is highly sheared, i.e. $B^{pol} / B^{tor} \equiv \arctan\theta$ is of order unity. An accurate analysis of the properties of ECE in these devices was required. The effect of large magnetic shear on the electron cyclotron emission spectra from the Large Helical Device (LHD) has been studied.

Usually the optically thick second harmonic extra-ordinary (X) polarisation mode is monitored in order to determine the temperature profile. It is important to select this single polarisation mode and not a mix of X and optically thin ordinary (O) mode.

In a sheared magnetic field, the propagation of X and O-mode polarisation is coupled, causing mode conversion and polarisation rotation. The propagation of ECE waves have been calculated by solving the coupled wave equations numerically over the path towards the diagnostic antenna [1]:

$$\frac{d^2E_{//}}{dr^2}+(\frac{\omega^2}{c^2}N_X^2-\phi^2)E_{//}=+2\phi\frac{dE_\perp}{dr}+E_\perp\frac{d\phi}{dr}, \quad (1a)$$

$$\frac{d^2E_\perp}{dr^2}+(\frac{\omega^2}{c^2}N_O^2-\phi^2)E_\perp=-2\phi\frac{dE_{//}}{dr}-E_{//}\frac{d\phi}{dr}, \quad (1b)$$

where, $E_\perp$ and $E_{//}$ are the X and O mode waves electric fields and ϕ is the radial derivative of the shear.

The presence of double emission resonance's, re-absorption and optical thickness have been included in the simulation program of ECE spectra. The optical thickness has been determined by integrating the absorption coefficient over the propagation path. Waves reflected by the vessel wall facing the diagnostic antenna will affect the measured ECE spectrum. Part of the reflected waves will be mode scrambled, thus yielding an additional complication.

It was found from the simulations that at low density mode conversion scrambles the ECE spectra. However, at higher density ($n_{eo} > 1 \cdot 10^{19}\ m^{-3}$) non-converted X-mode can be obtained.

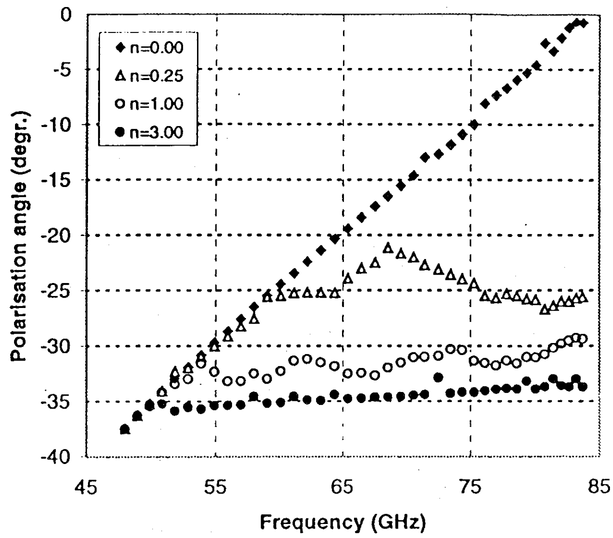

Figure 1: *The angle of the waves electric field vector with respect to the laboratory frame at the plasma edge. At low densities all frequencies exit the plasma with different polarisation angles. At higher densities the polarisation angle of the initial X-mode approaches 35°, which is perpendicular to the local magnetic field at the plasma edge.*

This polarisation mode leaves the plasma under a specific angle, $\beta=35\pm5°$, due to polarisation rotation. i.e. the polarisation rotates in the laboratory frame simultaneously with the field shear. This is shown in the figure above. The second harmonic X-mode is largely optically thick for these densities. Its spectrum was found to be unaffected by reflections and emission from the second resonance, which were re-absorbed by the plasma.

The polarisation of ECE spectra has been measured in LHD by means of an adjustable polarisation rotator in the waveguide system. The first preliminary results are in agreement with the simulations. If the polarisation rotator is utilised under a specific angle of $35°$, X-mode polarisation is selected by the waveguide system and fed to the ECE diagnostic. Of course sufficient density is required and from $n_{eo} = 1.0 - 3.0 \cdot 10^{19}\ m^{-3}$ ($B=1.5$ T) and $n_{eo} = 2.0 - 13 \cdot 10^{19}\ m^{-3}$ ($B=3$ T), the spectra can be applied for temperature profile analysis.

First temperature profiles have been obtained by means of ECE spectroscopy on LHD. More detailed measurements of the spectral polarisation will be carried out in the next experimental campaign of LHD.

References

[1] I. Fidone and G. Granata, Nucl. Fusion **11** (1971) 133.