Evaluation of ECE spectra on the oblique propagation and application to electron temperature measurement in a reactor grade tokamak

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The electron temperature (T_e) measurement from electron cyclotron emission (ECE) has been useful diagnostics in magnetic confinement devices. The importance of relativistic effect on the electron temperature measurement has been well recognized in reactor grade plasma [1]. The direction of ECE observation is perpendicular to magnetic field normally. When the direction is changed from perpendicular to oblique, the relativistic effect reduces, and the Doppler effect increases. So, in order to evaluate these effects in the case of oblique propagation, the radiance of ECE is evaluated by a numerical calculation.

The equation of emissivity in the oblique propagation for spherically-symmetric relativistic Maxwellian velocity distribution function is derived. The equation is the extension of Trubnikov equation which is emissivity for the perpendicular propagation for the relativistic Maxwellian velocity distribution function [2]. The emissivity for contribution of the parallel electron velocity is as follows:

$$\eta_{\omega}^{//}(\omega,\theta_B)=\frac{\omega_p^2}{\omega_H c}\frac{\omega^2\,T_e}{8\pi^3 c^2}\frac{\pi\mu^2}{K_2(\mu)}$$

$$\sum_{n\geq x(1-\beta\cos\theta_p\cos\theta_B)}^{\infty}\frac{n^2}{x^4}\int_0^{\pi}d\theta_p sin\theta_p\left(\frac{\cos\theta_B-\beta\cos\theta_p}{sin\theta_B}\right)^2 J_n^2\left(\frac{n\beta sin\theta_p sin\theta_B}{1-\beta\cos\theta_p\cos\theta_B}\right)$$

$$\frac{1}{(1-\beta\cos\theta_p\cos\theta_B)^3}\sqrt{\left(\frac{n}{1-\beta\cos\theta_p\cos\theta_B}\right)^2-x^2}\exp\{-[\frac{\mu}{X}(\frac{n}{1-\beta\cos\theta_p\cos\theta_B})]\}$$

where

$$\beta=\frac{\cos\theta_B\cos\theta_p\pm\sqrt{(\cos\theta_B\cos\theta_p)^2-\{(\cos\theta_B\cos\theta_p)^2+(n\omega_H/\omega)^2\}\{1-(n\omega_H/\omega)^2\}}}{(\cos\theta_B\cos\theta_p)^2+(n\omega_H/\omega)^2}.$$

The β is restricted be positive. Notations are based on that used in the Trubnikov equation [2]. The ω_H, ω_p, θ_p, J_n, K_2 are the non-relativistic EC angular frequency, plasma angular frequency, angular coordinate in the momentum space, n-th Bessel function, and 2nd modified Bessel function, respectively. $\mu = mc^2/T_e$, $x = \omega/\omega_H$. The n, $d\theta_p$, and $\beta\cos\theta_p$ in the Trubnikov equation are interpreted as $n/(1-\cos\theta_p\cos\theta_B)$, $d\theta_p/(1-\cos\theta_p\cos\theta_B)$, $(\cos\theta_B-\beta\cos\theta_p)/\sin\theta_B$ in the equation.

The emission and absorption processes in the plasma are described in the radiation transfer equation. The emissivity is calculated using the obtained emissivity equation and the absorption coefficient is obtained from the emissivity applying Kirchhoff's law. The ECE spectra in the oblique propagation and application to electron temperature measurement in reactor grade tokamak will be presented in the conference.

References

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[2] B. A. Trubnikov: *Magnetic Emission of High-Temperature Plasma, Thesis, Institute of Atomic Energy, Moscow, 1958.*