§18. Evolution of Full Stokes Parameters of Electron Cyclotron Waves with Hot Plasma Effects

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In general, there are no orthogonal eigenpolarizations when the absorption or the dichroism is taken into account. In the cases of the circular and linear dichroism, there are two orthogonal eigenpolarizations. The perpendicular injection heating scenario was investigated using the evolution equation with a differential Mueller matrix for full Stokes parameters, that was deduced from a Jones matrix using the coherence vector[1]. The differential Mueller matrix was deduced in a slab geometry based on the WKB approximation, and then the local refractive indexes without the shear effect were used. In the previous work, two orthogonal polarization states for eigenmodes, which are located on just the opposite sides of the Poincaré sphere, were treated. The evolution equation of full Stokes parameters in general cases, where the polarization states of two eigenmodes are not orthogonal, is obtained here, and is applied to analyze the subject on LHD.

Each component of the full Stokes parameters is in the term of S_i $(i = 0, 1, 2, 3)$ to express the polarization states including the intensity. The full Stokes parameters for the slow and fast modes of the characteristic waves are expressed with the intensity $I_{\mathrm{s,f}}$ and with the azimuth angle and the ellipticity $\psi_{\mathrm{s,f}}$ and $\chi_{\mathrm{s,f}}$. Here, the subscriptions, s and f, denote the slow and fast modes, respectively. The full Stokes parameters of the propagating waves, which are treated as the resulting summation of the two characteristic waves, are described as the followings,

$$\mathbf{S} = \mathbf{A} \cdot \mathbf{X}, \qquad \mathbf{X} = (\ I_{\mathrm{s}}, I_{\mathrm{f}},\ 2\sqrt{I_{\mathrm{s}} I_{\mathrm{f}}}\cos\delta,\ 2\sqrt{I_{\mathrm{s}} I_{\mathrm{f}}}\sin\delta).$$

Here, the quantity δ is the phase retardance between the slow and fast characteristic waves, $\delta = \phi_{\mathrm{s}} - \phi_{\mathrm{f}}$. The matrix $\mathbf{A}$ are in terms of $\psi_{\mathrm{s,f}}$ and $\chi_{\mathrm{s,f}}$[1]. Using the matrix $\mathbf{A}$, the evolution equation in the full Stokes parameters $\mathbf{S}$ is written by

$$\frac{\mathrm{d}\mathbf{S}}{\mathrm{d}z} = \mathbf{M} \cdot \mathbf{S}, \qquad \mathbf{M} = \mathbf{A} \cdot \mathbf{D} \cdot \mathbf{A}^{-1}.$$

Here, the matrix $\mathbf{M}$ is the differential Mueller matrix for the general case. The matrix $\mathbf{D}$ is a operator in the differential equation on the matrix $\mathbf{X}$, that shows the derivative of $\mathbf{X}$ on the propagating z axis. The matrix components are described with a real and a imaginary part of the complex refractive indexes for the slow and fast modes , $n_{\mathrm{s,f}}$ and $\kappa_{\mathrm{s,f}}$. A determinant of the matrix $\mathbf{A}$ can be evaluated as the terms of the reduced Stokes parameters for both of two characteristics waves as $det\mathbf{A} = -(1.0 - \mathbf{s}_{\mathrm{s}} \cdot \mathbf{s}_{\mathrm{f}}) + |\mathbf{s}_{\mathrm{s}} \times \mathbf{s}_{\mathrm{f}}|^2/2$, which can be reduced to the value of -2 in the case of two orthogonal eigenpolarizations(*i.e.* $\mathbf{s}_{\mathrm{s}} = -\mathbf{s}_{\mathrm{f}}$). The derivation of the matrix $\mathbf{M}$ is tedious, but is given in ref.[2]. Using the complex refractive index and the reduced Stokes parameters, this evolution equation in the full Stokes parameters may be treated and applied to the second harmonic heating on the LHD.

The plasma with the central peaked electron temperature(about 2keV) is initially produced by the 82.7GHz gyrotron at the 2nd harmonic heating. The electron density is about $1.0 \times 10^{19}\mathrm{m}^{-3}$ with a rather flat profile. This target plasma is additionally heated with the 84GHz gyrotron. The launcher at the Upper side port is used to this additional heating. This additional heating can be treated as the quasi-perpendicular injection case. In order to use the obtained equation, the reduced Stokes parameters for the slow and fast modes are first deduced. The three components on the reduced Stokes parameters of $(\mathbf{s}_{\mathrm{s}} + \mathbf{s}_{\mathrm{f}})_{1,2,3}$ are not zero near the resonance area. These components were neglected at the previous work where $\mathbf{s}_{\mathrm{s}} = -\mathbf{s}_{\mathrm{f}}$, because of the treatment as the pure-perpendicular injection case. They are however taken into account correctly in this work. The change of the diamagnetic signal when the 84GHz gyrotron is turned on is used to evaluate the absorption power. Figure 1 shows the absorption power and the calculated single path absorption rate when the $\lambda/4$ polarizer is rotated. The absorption rate is calculated as the term of $[1 - S_0]$ after the single path. The dependence of the absorption power is qualitatively consistent with the single path absorption rate calculated using the obtained equation.

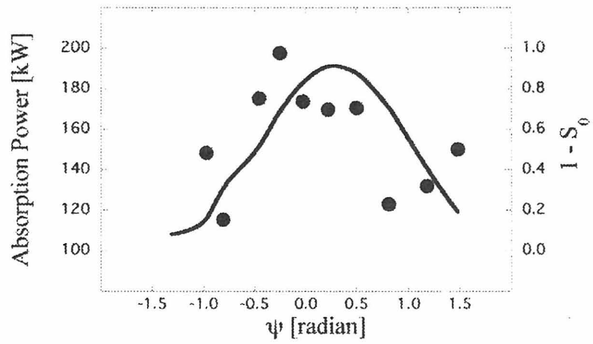

Fig. 1: The absorption power by the diamagnetic signal and the calculated rate.

Reference

[1] Idei H et al. 2000 in *Proceedings of the 27th EPS Conference of Plasma Phys. and Controlled Fusion.*

[2] Idei H et al., 2002, in *Proceedings of the EC-12 Workshop.*