

Electron Cyclotron Radiative Transfer In the Presence of Polarization Scrambling in Wall Reflections

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INTRODUCTION

- **polarization scrambling** has to be accounted for in the diagnostics based on electron cyclotron (EC) emission

[A.E. Costley et al., Phys. Rev. Lett., 1974, **33**, 758]
 [I.H. Hutchinson and D. S. Komm, Nucl. Fusion, 1977, **17**, 1077]
 [R.M.J. Sillen et al., Nucl. Fusion, 1986, **26**, 303]

- This effect has also been considered in the context of EC plasma heating

[S. Nowak et al., Fusion Engineering and Design, 2001, **53**, 315]

- **What is the impact that such an effect might have on the EC radiative transfer in fusion plasmas?**

↳ importance on transport studies and passive EC current generation

So far only CYTRAN routine (from S. Tamor) and a formal approach:
 [W. Kernbichler and S. V. Kasilov, Phys. Plasmas, 1996, **3**, 4128]

polarization scrambling parameter

$p (\leq 1) \rightarrow$ percentage of radiation transferred from one mode to the other in each reflection

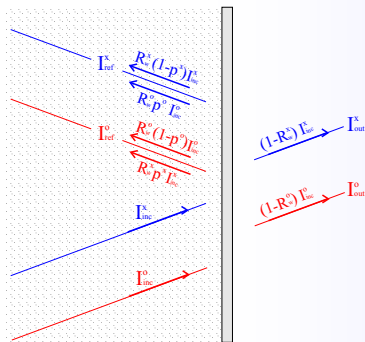


Figure 1: Schematic diagram of I -transfer during wall reflection through polarization scrambling.

AN EXACT ANALYTICAL SOLUTION OF THE RTE ACCOUNTING FOR POLARIZATION SCRAMBLING

For a cylindrical system with specularly reflecting walls,

$$\frac{I^\sigma(s)}{(N_r^\sigma(s))^2} = i^\sigma(s, s_0) + I_{ref}^\sigma(s_0) e^{-\tau^\sigma(s, s_0)}$$

$$I_{ref}^\sigma(s_0) = \frac{1}{1 - R_{eff}^{\sigma\sigma'} e^{-\tau^\sigma}} \left[\underbrace{R_{eff}^{\sigma\sigma'} i^\sigma}_{\text{1st term}} + \underbrace{\frac{R_w^{\sigma\sigma'} p^{\sigma\sigma'} R_w^\sigma - R_{eff}^{\sigma\sigma'}}{R_w^{\sigma\sigma'} p^{\sigma\sigma'} - 1 - R_w^{\sigma\sigma'} e^{-\tau^\sigma}} i^{\sigma'}}_{\text{2nd term}} \right] \quad (\sigma \neq \sigma')$$

with $\tau^\sigma(s, s') \equiv \int_s^{s'} ds'' \alpha^\sigma(s'')$ the optical depth,

$$i^\sigma(s, s_0) = \frac{\omega^3}{8\pi^3 c^2} \int_{s_0}^s ds' T(s') \alpha^\sigma(s') e^{-\tau^\sigma(s, s')}$$

$$R_{eff}^{\sigma\sigma'} = R_w^{\sigma\sigma'} \left[1 - p^{\sigma\sigma'} \frac{1 - R_w^{\sigma\sigma'} e^{-\tau^\sigma}}{1 - R_w^{\sigma\sigma'} (1 - p^{\sigma\sigma'}) e^{-\tau^\sigma}} \right]$$

- For the $\sigma = x$ -mode interacting strongly with the plasma

→ The 1st term is larger → $I^x \searrow$ (softly)

- For the $\sigma = o$ -mode weakly interacting with the plasma

→ The 2nd term is dominant → $I^o \nearrow$

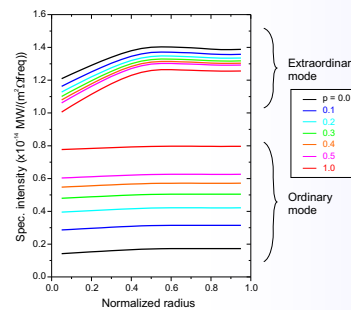


Figure 2: Specific intensities for ITER-like parameters and $R_w = 0.6$ for a ray with $\omega = 8\omega_c$ and solid angle $\Omega \equiv$ [crossing the plasma centre in a cross-section perpendicular to the magnetic field]

EFFECT ON THE NET EC RADIATIVE POWER DENSITY

... a quantification for the upper limit of polarization scrambling effects

$$\frac{dP_{EC}(\mathbf{r})}{dV} \propto \sum_{\sigma=x,o} \int_{\omega} d\omega \int_{\Omega} d^2\Omega_s \alpha^\sigma (I_{bb}^\sigma - I^\sigma)$$

- when $p^x \nearrow \Rightarrow dP_{EC}^x/dV \uparrow$
 - when $p^x \nearrow \Rightarrow dP_{EC}^o/dV \searrow$
- the total $dP_{EC}/dV \uparrow$ since $(I^o \nearrow)$ is REDUCED in the average integration over Ω

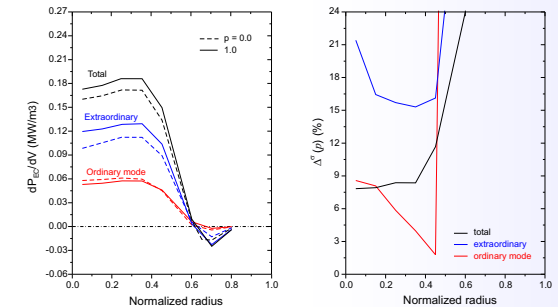


Figure 3: The net EC radiative power density for ITER-like parameters and $R_w = 0.8$ (above); dependence of the total EC power loss (right) on the value of p for $R_w = 0.8$ and 0.6 .

$$\frac{dP_{EC}/dV}{dV} = \frac{dP_{EC}/dV}{dV}|_{p=0} + C_p p^x$$

fitting with x_p about 0.4-0.6

IN CONCLUSION,

- polarization scrambling is found to significantly enhance I^o at the expense of a weakening of I^x (for rays propagating at $\theta \sim \pi/2$)
- ↳ impact on the passive EC current generation in a fusion plasma?
- polarization scrambling turns out to influence only weakly the net EC radiative power density and the total EC power loss