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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 (≤ 1) ⟹ percentage of radiation transferred from one mode to the other in each reflection

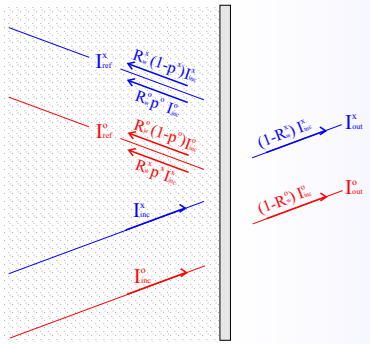


Figure 1: Schematic diagram of I-transfer during wall reflection through polarization scrambling.

AN EXACT ANALYTICAL SOLUTION OF THE RTE ACCOUNTING FOR POLARIZATION SCRAMBLING

For a cylindrical system with specularly reflecting walls,

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

$$I^\sigma_{ref}(s_0) = \frac{1}{1-R^{\sigma\sigma'}_{eff}e^{-\tau^{\sigma'}}}\left[R^{\sigma\sigma'}_{eff}\,i^{\sigma'} + \frac{R^{\sigma'}_w p^{\sigma'}}{R^{\sigma}_w p^{\sigma}}\frac{R^{\sigma}_w - R^{\sigma\sigma'}_{eff}}{1-R^{\sigma'}_w e^{-\tau^{\sigma'}}}\,i^{\sigma'}\right] \quad (\sigma \neq \sigma')$$

1st term 2nd term

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

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

$$R^{\sigma\sigma'}_{eff} = R^\sigma_w\left[1 - p^\sigma\frac{1-R^{\sigma'}_w e^{-\tau^{\sigma'}}}{1-R^{\sigma'}_w(1-p^{\sigma'})e^{-\tau^{\sigma'}}}\right]$$

when p^x ↗

- For the σ = *x*-mode interacting strongly with the plasma ⟹ The 1st term is larger ⟹ I^x ↘ (softly)
- For the σ = *o*-mode weakly interacting with the plasma ⟹ The 2nd term is dominant ⟹ I^o ↗↗

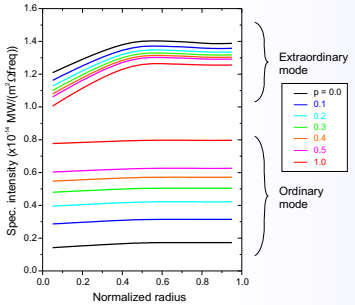


Figure 2: Specific intensities for ITER-like parameters and $R_w = 0.6$ for a ray with $\omega = 8\omega_c$ and solid angle $\Omega \equiv$ [crossing the plasma centre in a cross-section perpendicular to the magnetic field]

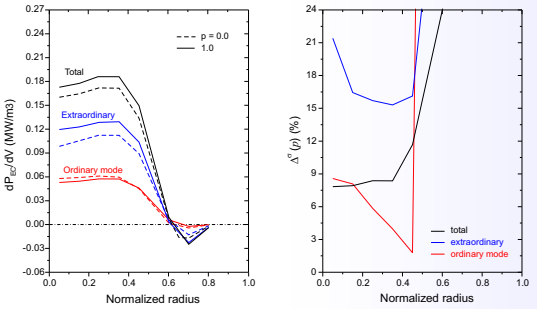
EFFECT ON THE NET EC RADIATIVE POWER DENSITY

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

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

- when p^x ↗ ⟹ dP^x_{EC}/dV ↗
- when p^x ↗ ⟹ dP^o_{EC}/dV ↘

the total dP_{EC}/dV ↗ since (I^o ↗↗) is REDUCED in the average integration over Ω



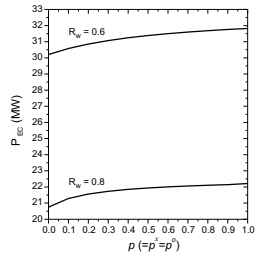


Figure 3: The **net EC radiative power density** for ITER-like parameters and $R_w = 0.8$ (above); dependence of the **total EC power loss** (right) on the value of p for $R_w = 0.8$ and 0.6.

$dP_{EC}/dV = dP_{EC}/dV|_{p=0} + C_1 p^{x_p}$
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