HHFW Modeling of Current Drive and Edge Turbulence Scattering

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Three Tasks in Support of HHFW Campaign

- Investigate scattering of HHFW by edge turbulence.

- Investigate HHFW CD model in CURRAY, and compare with AORSA and CQL3D/GENRAY.

- Complete incorporation of CURRAY CD into TRANSP for non-zero E_{dc}.

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Modeling Edge Turbulence Scattering of HHFW

- Scattering of HHFW by edge density fluctuations can contribute to the observed degradation of heating efficiency with lower $k_{||}$, as suggested by Ono.

- Scattering may lead to altered wave propagation characteristics and paths in the plasma periphery, and to coherent wave energy lost to the fluctuating components.

- We propose to investigate this phenomenon using a modified ray tracing code in two ways:
  - Perturbation approach [Keller] √
  - Monte-Carlo like approach [Bonoli & Ott, PF25('82)359]

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Keller's Perturbation Method

- Based on Antani & Kaup, Phys. Fluids 27 (1984) 1169.
  - Scattering of coherent Whistler wave from random density fluctuations
- Density fluctuations modify cold plasma dispersion tensor:

$$K_{\perp} = K_{\perp 0} + (K_{\perp 0} - 1)(\delta n / n)$$
$$K_x = K_{x0}(1 + \delta n / n)$$
$$K_{\parallel} = K_{\parallel 0}(1 + \delta n / n)$$

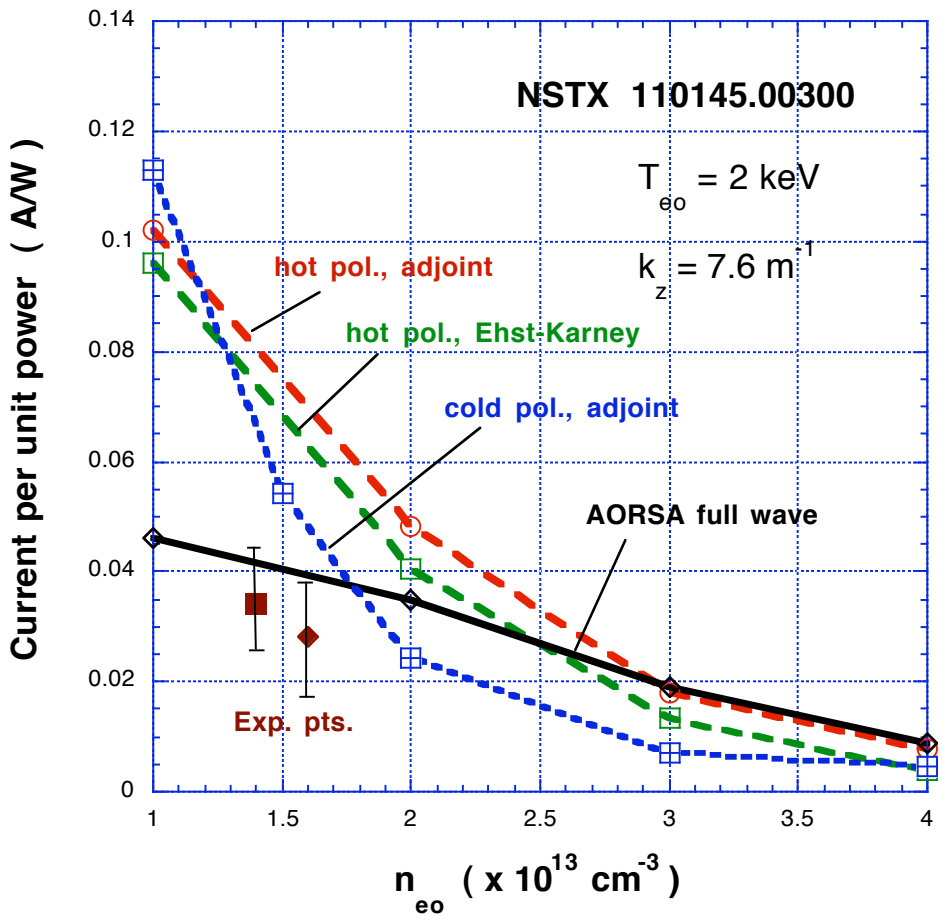
  - Wave equation: $\left(D + (\delta n / n) M\right) \bullet \vec{E} = 0$
  - Assuming small fluctuating part, one solves the modified dispersion relation and gets

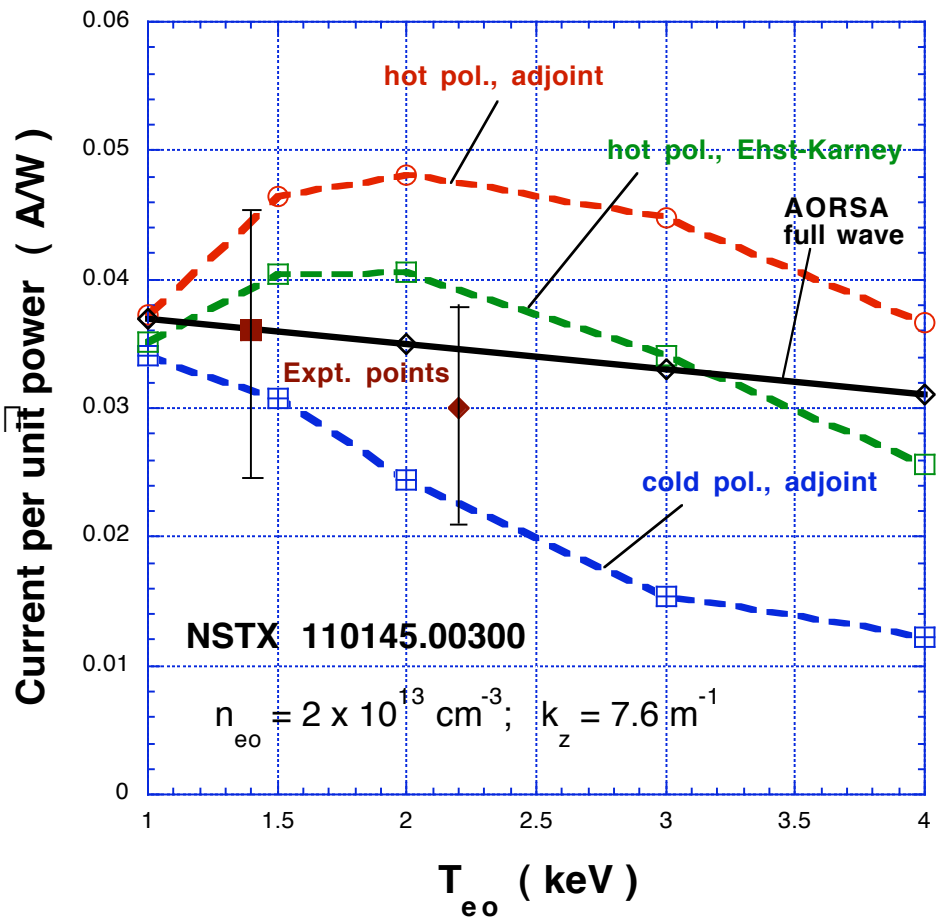
$$\mathrm{Re}(n_{\perp}^2) = n_{\perp 0}^2 + \Delta(\Delta^4 \bar{\ell}^4)$$
$$\mathrm{Im}(n_{\perp}^2) = \Delta(\Delta^2 \bar{\ell}^2)$$

where $\Delta = \left\langle (\delta n / n)^2 \right\rangle^{1/2}$ and $\bar{\ell} = (c / \Omega) / L_T$, L_T is correlation length.

- Use $\mathrm{Im}(n_{\perp})$ in ray tracing code to calculate scattered and dissipated wave power as the wave passes through edge turbulence region.

Comparison of CURRAY CD Results with AORSA and Experiments Warrants Further Investigation





- cold polarization : Use $k_{\square}$ from ray tracing in evaluating K_{ij}'s.
- hot polarization : Use complex $k_{\square}$ from order reduction to evaluate K_{ij}'s.

Detailed Investigation of CD Model in CURRAY

- Recent comparison of CURRAY CD Results with AORSA and with experimental data reveals disagreement over certain parameter regimes. We will examine the cause(s) of these differences, and upgrade the physics models accordingly to make CURRAY CD model more robust.

- Suggested approaches:

  - Make sure wave absorption physics agrees with other codes over a wide range of parameters ($k_{||}$, n_e, T_e, etc). Consider using exact complex $k_{\square}$ used in damping calculations.
  - Follow ray through with local j/p calculation from adjoint code and check with results from generated j/p table.
  - Compare with CQL3D/GENRAY results to assess the significance of RF-induced velocity diffusion, in the NSTX parameter range.

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Complete Integration of CURRAY CD ($E_{dc} \neq 0$) into TRANSP

- There is the need to evaluate $j_{rf}(E_{dc})$ and $\partial j_{rf} / \partial E_{dc}$ in modeling current transients during HHFW current ramp-up, in order to avoid numerical problems in solving current diffusion equation (Ignat).

- Original plan is to generate a table of j/p (θ,ϕ,w,E_{dc}), by incorporating features of the Karney-Fisch adjoint code (nonzero E_{dc} , no trapping) into the present CURRAY model (zero $E_{dc,}$ with trapping). This has been found to be very time-consuming.

- We now propose to use the CQL3D kinetic code combined with either CURRAY or GENRAY to carry out the calculations.
  - CQL3D solves the rf quasilinear diffusion equation with a non-zero E_{dc}.
  - Will decide if generating a suitably limited look-up table for j/p (θ,ϕ,w,E_{dc}), or direct evaluation, is the best approach.

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