EMISSION OF ELECTRON BERNSTEIN WAVES

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PROPAGATION OF EC WAVES (COLD PLASMA)

$$K_\perp \frac{d^2 E_y}{dx^2} + \frac{\omega^2}{c^2}\left(K_\perp^2 - K_X^2 - n_\parallel^2 K_\perp\right) E_y = k_\parallel K_X F_y$$

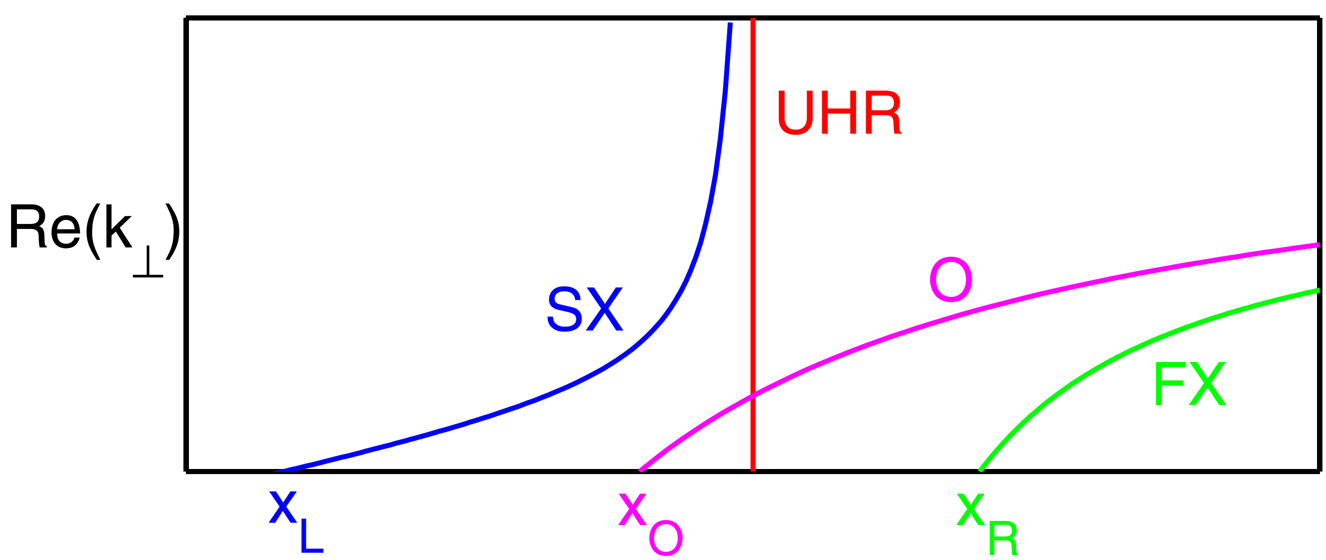
$(K_\perp = 0 \implies$ upper hybrid resonance$)$

$$\frac{d}{dx}\left[\frac{1}{K_\parallel}\frac{dF_y}{dx}\right] + \frac{\omega^2}{c^2}\left(1 - \frac{n_\parallel^2}{K_\perp}\right) F_y = k_\parallel \frac{\omega^2}{c^2}\frac{K_X}{K_\perp} E_y$$

where $F_y = i\omega B_y$, $n_\parallel = ck_\parallel/\omega$,

$K_\perp = 1 - \frac{\omega_{pe}^2}{\omega^2 - \omega_{ce}^2}$, $K_X = -\frac{\omega_{ce}}{\omega}\left(\frac{\omega_{pe}^2}{\omega^2 - \omega_{ce}^2}\right)$, and

$K_\parallel = 1 - \frac{\omega_{pe}^2}{\omega^2}$.



CONDITIONS FOR MODE CONVERSION

- Necessary condition: $f > f_{\rm edge}^{\rm UHR} = \sqrt{f_{pe}^2 + f_{ce}^2}$
- Relevant parameter:

$$\eta \approx \frac{\omega_{ce} L_n}{c\alpha}\left[\sqrt{1+\alpha^2} - 1\right]^2$$

  where $\alpha = \omega_{pe}/\omega_{ce}$ at the upper hybrid resonance.

- For X-B mode conversion:
  - $n_\parallel < n_{\parallel,opt} = (1 + f_{pe}/f_{ce})^{-1/2}$
  - $0.05 \lesssim \eta \lesssim 0.6 \Longrightarrow$

$$1.3 \times 10^{-2} \text{ T cm} \lesssim |BL_n| \lesssim 0.16 \text{ T cm}$$

- For O-X-B:
  - $n_\parallel \sim n_{\parallel,opt}$
  - $\eta > 1.$
- For NSTX:
  - X-B mode conversion: $f \approx 15$ GHz and $n_\parallel \approx 0$
  - O-X-B mode conversion: $f \approx 28$ GHz and $n_{\parallel,opt} \approx 0.5$

EMISSION OF ELECTRON BERNSTEIN WAVES

- Geometric optics analysis shows that EBWs are strongly damped on electrons in the vicinity of Doppler-shifted electron cyclotron resonance (and its harmonics)

  $\Rightarrow$ EBWs would also be emitted from these resonance layers.

- EBWs mode convert to X and O modes at the upper hybrid resonance (usually near the plasma edge in NSTX)

- Analytical and computational models have been developed to study the mode conversion process and its dependence on plasma parameters.

- The fraction of EBW power converted to X mode and to O mode is directly related to the power mode converted from the X mode to EBWs and from O mode to EBWs

  $\Rightarrow$ experiments on heating and current drive by EBWs can be designed on the basis of the emitted radiation.

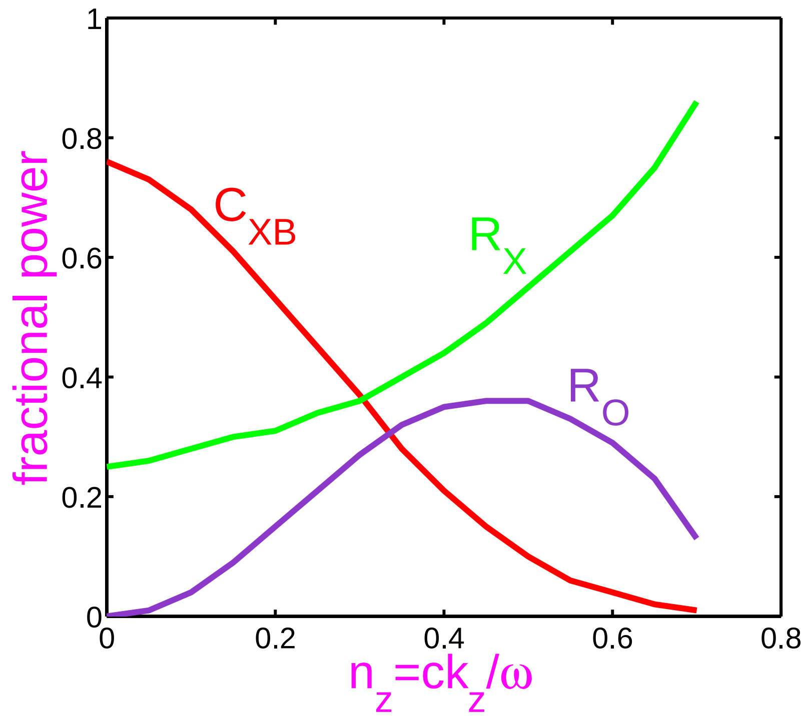
SIMULATIONS OF MODE CONVERSION

- Full wave analysis
  - slab geometry
  - sheared magnetic field
  - density and temperature profiles (∇n, $\nabla T \perp \vec{B}_0$)

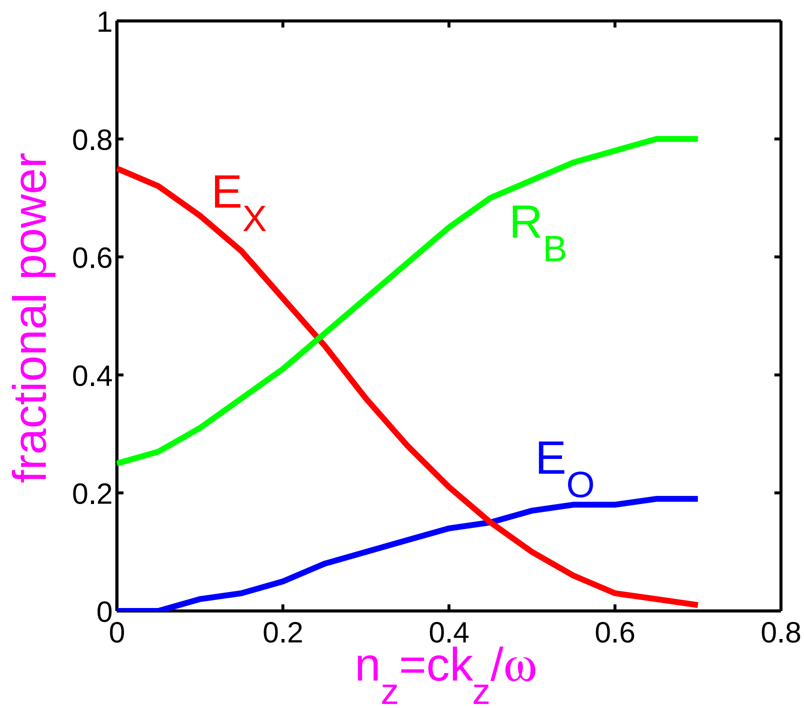
- Kinetic model of the plasma waves
  - propagation of X mode, O mode, and EBW
  - calculate the actual kinetic power flow in the electron Bernstein waves.

MODE CONVERSION OF X MODE TO EBW

(NSTX-type parameters, $f = 14$ GHz, $k_y = 0$)



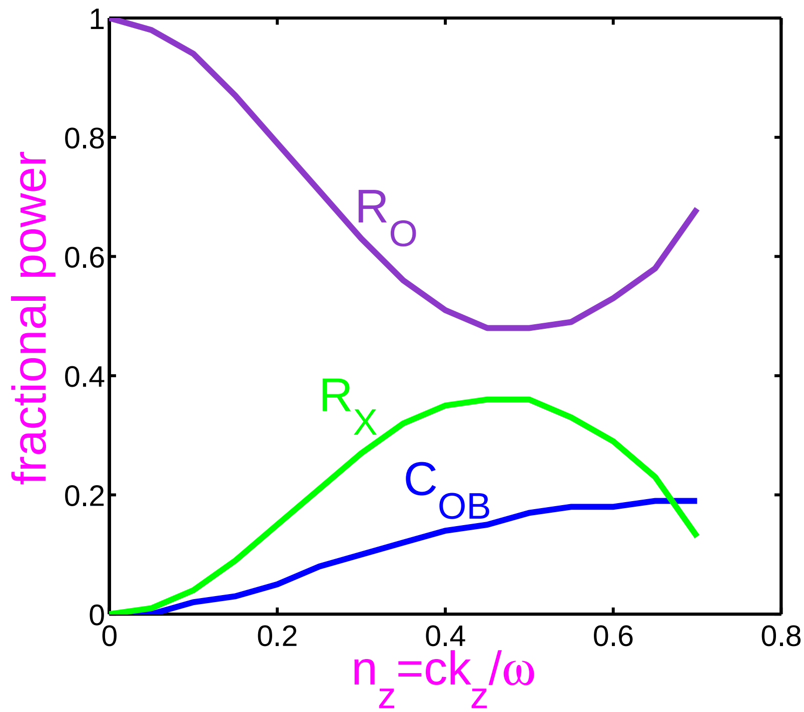
EMISSION OF X AND O MODES



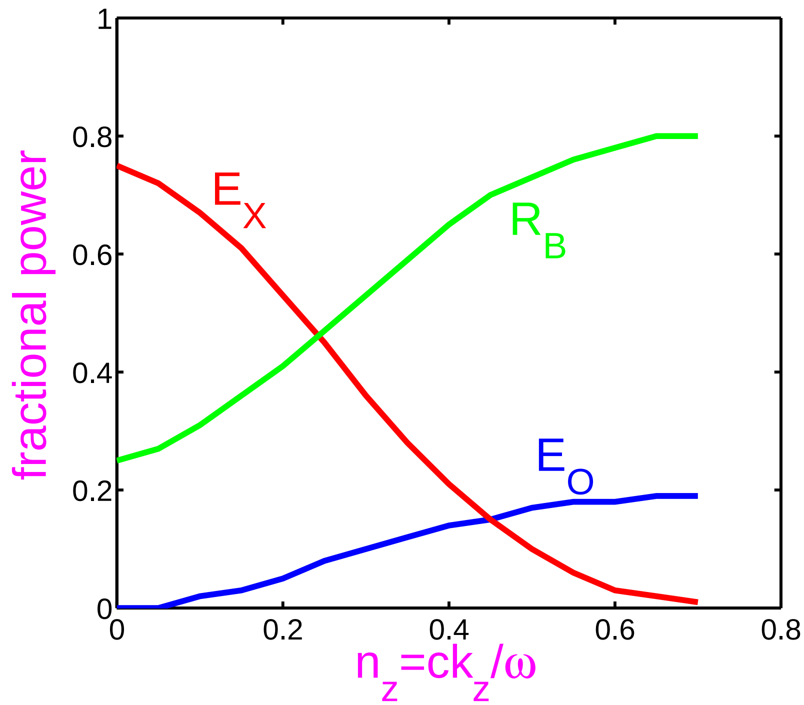
- $E_X = C_{XB}$

MODE CONVERSION OF O MODE TO EBW

(NSTX-type parameters, $f = 14$ GHz, $k_y = 0$)



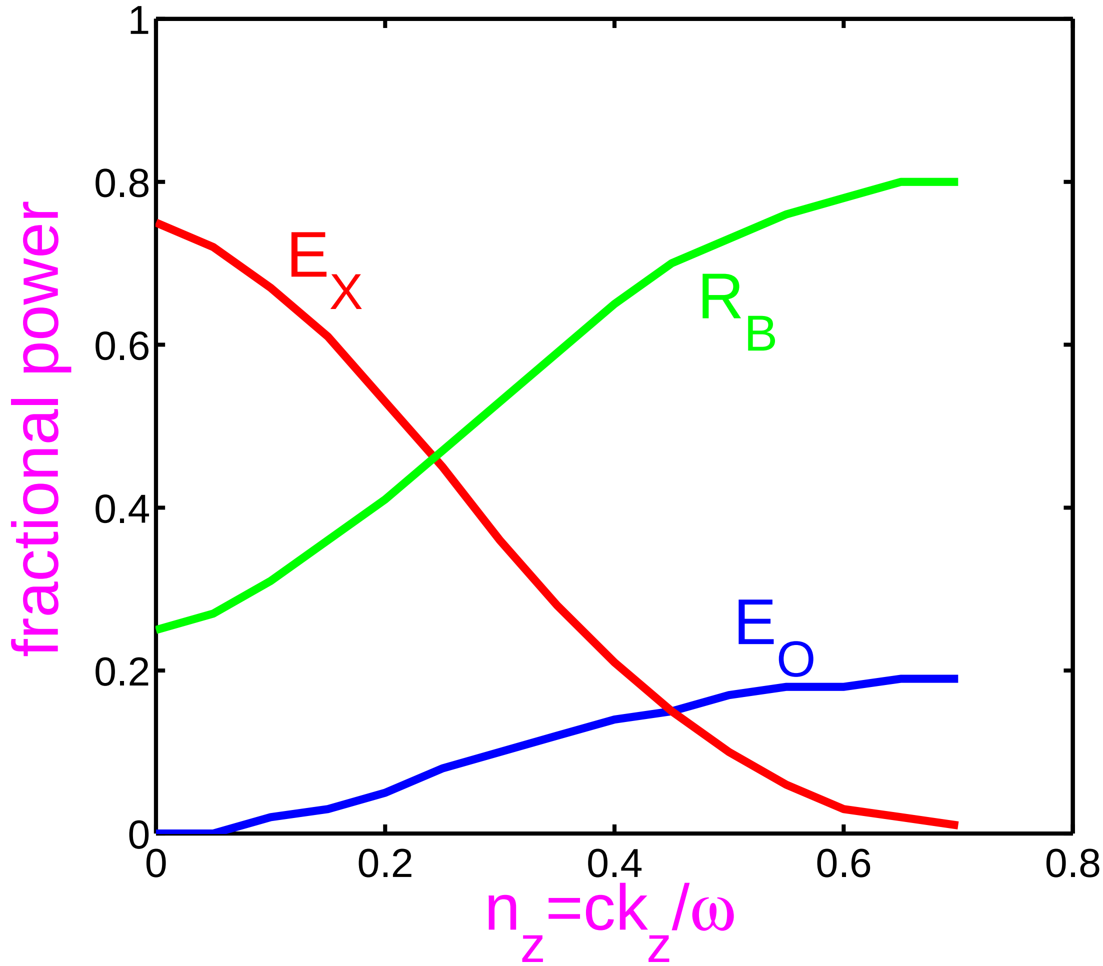
EMISSION OF X AND O MODES



- $E_O = C_{OB}$

EMISSION OF X AND O MODES

(NSTX-type parameters, $f = 14$ GHz, $k_y = 0$)



- $E_X = C_{XB}$, $E_O = C_{OB}$