SBS in Multiple-Species Plasmas

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Summary

We developed a model to study fast- and slow-wave SBS and how nonlinearities affect them

• Fast-wave SBS reflectivities are
  – significantly reduced by nonlinear saturation for $T_e/T_i \gtrsim 10$
  – not affected by nonlinear saturation for $T_e/T_i \lesssim 5$

• In CH plasmas, slow-wave SBS reflectivity is much lower than fast-wave SBS reflectivity.

• Slow-wave SBS reflectivities are significantly increased by nonlinear effects, but remain much smaller than fast-wave SBS.
Outline

- Description of the model
- Fast-wave SBS at low and high ion temperatures
- Slow-wave SBS
- Conclusions
We modeled SBS in CH plasmas at OMEGA-like parameters

- We modeled backscattering using a one-dimensional fluid model with phenomenological Landau-damping terms.
- Light wavelength: 0.35 μm
- Pump intensity: \( I = 2.45 \times 10^{15} \frac{W}{cm^2} \)
- Electron density: \( \frac{n_e}{n_{cr}} = 0.46 \)
- Electron temperature: \( T_e = 1 \text{ keV} \)
Model consists of electron density, ponderomotive potential, ion-fluid equations, and Poisson equations

- **Electron density:** \( n_e = \exp(\varphi) - P = 1 + \delta n_e \)

- **Ponderomotive potential:** \( \partial_x P = \alpha \Im \left( n_{e1} \right) \sqrt{P^2 + C^2} \),
  \( \alpha = \left( v_e / c \right)^2 / k_s \), \( C = |a_0|^2 + |a_1|^2 \)

- **Ion-fluid equations for species “s”:**
  \[
  \partial_t n_s + \partial_x (n_s u_s) + \lambda n_s = 0
  \]
  \[
  \partial_t u_s + u_s \partial_x u_s + \beta_s \partial_x \varphi + \gamma_s \nu_{\text{th}s} n_s^{\gamma_s - 2} \partial_x n_s + \lambda u_s = 0
  \]

- **\( \lambda \)-Landau damping coefficients; \( \gamma_s \)-polytropic indeces:** \( \beta_s = \frac{z_s M_r}{z_r M_s} \)

- **Poisson equation:** \( \partial_{xx} \varphi - n_e + \sum_{s=\ell,h} \alpha_s n_s = 0; \quad \alpha_s = Z_s n_{0s} / n_{0e} \)
Results of kinetic model\textsuperscript{1} are used to close the system of fluid Equations

- $\gamma = 3$ gives best agreement between fluid and kinetic phase velocities.
- Phenomenological damping terms correspond to imaginary parts of kinetic frequencies.

Damping of fast wave increases with ion temperature

- Due to exponential dependence on damping, fast-wave SBS reflectivity decreases fast with increasing ion temperature.

- For \( T_e/T_i = 5, \gamma/\omega_{pi} = 1.56 \times 10^{-2}, R_{fast} = 3\% \rightarrow \) IA wave amplitude is small \( \rightarrow \) nonlinearities are weak.
For $T_e/T_i = 10$, damping is small and fast-wave SBS reflectivity is large

- $\gamma/\omega_{pi} = 10^{-2} \Rightarrow R_{\text{fast}} = 44\%$
  IA wave amplitude is large enough to be affected by nonlinear saturation.

- The two-harmonics model\(^1\) (THM) has been extended for two-ion plasmas.

In CH plasmas slow-wave SBS reflectivity is much smaller than fast-wave SBS reflectivity

- In slow-wave protons are pushed away from carbon ions shielding $\phi$ and thus reducing $\delta n_e$ and $R_{slow}$.
- For $I = 2 \times 10^{15} \text{ W/cm}^2$, slow-wave SBS is below threshold.
- For $I = 7 \times 10^{15} \text{ W/cm}^2$, $T_e/T_i = 10 \gamma/\omega_{pi} = 10^{-2}$ and $R_{slow} = 1\%$.
- Nonlinear saturation for $\delta n_h \gg \delta n_c \rightarrow$ increase in $\delta n_e$. 

![Graph](image.png)
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- Application of our model to different component plasmas is underway