Considerations for the Two-Stream Instability in Debris-Ion Stopping

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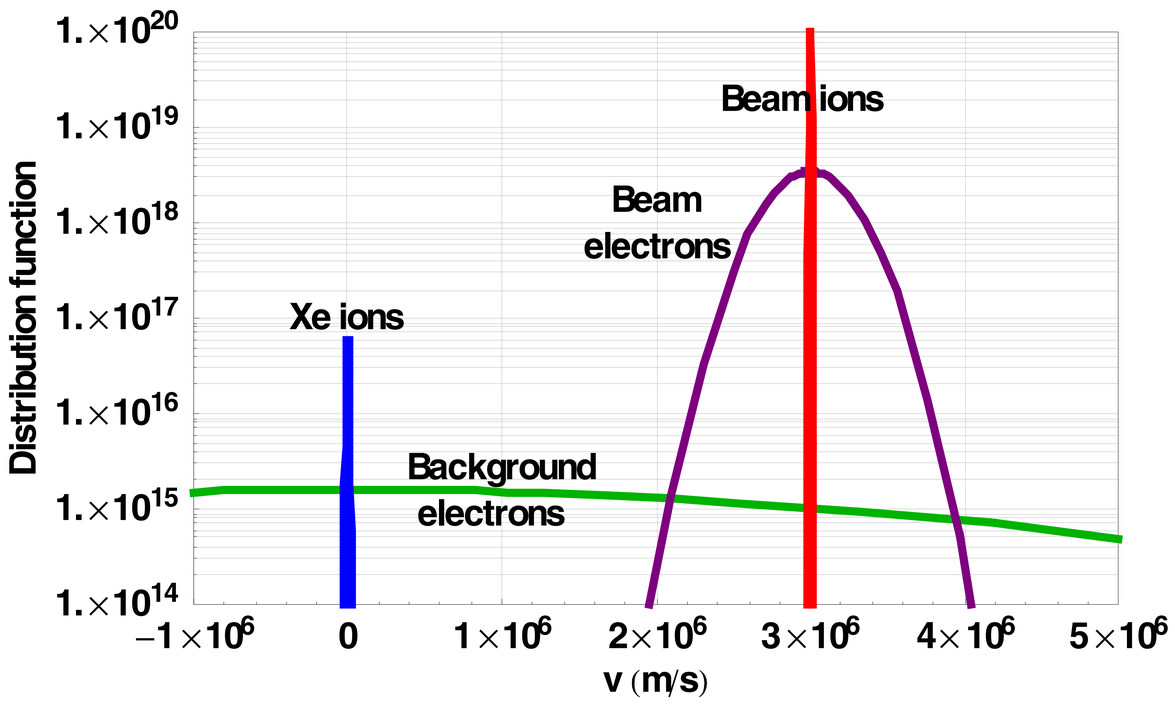
- The question of two-stream instabilities in IFE chambers arose at the previous HAPL meeting.
- The simplest case of two beams (ions on electrons) with delta-function distributions indicates instability.
- The actual problem is much more complicated.
  - Four species contribute: beam (blast wave) ions and electrons impact background electrons and Xe ions.
  - Distribution functions are Maxwellians or even more complicated distributions.

Distribution Functions Assuming Maxwellians

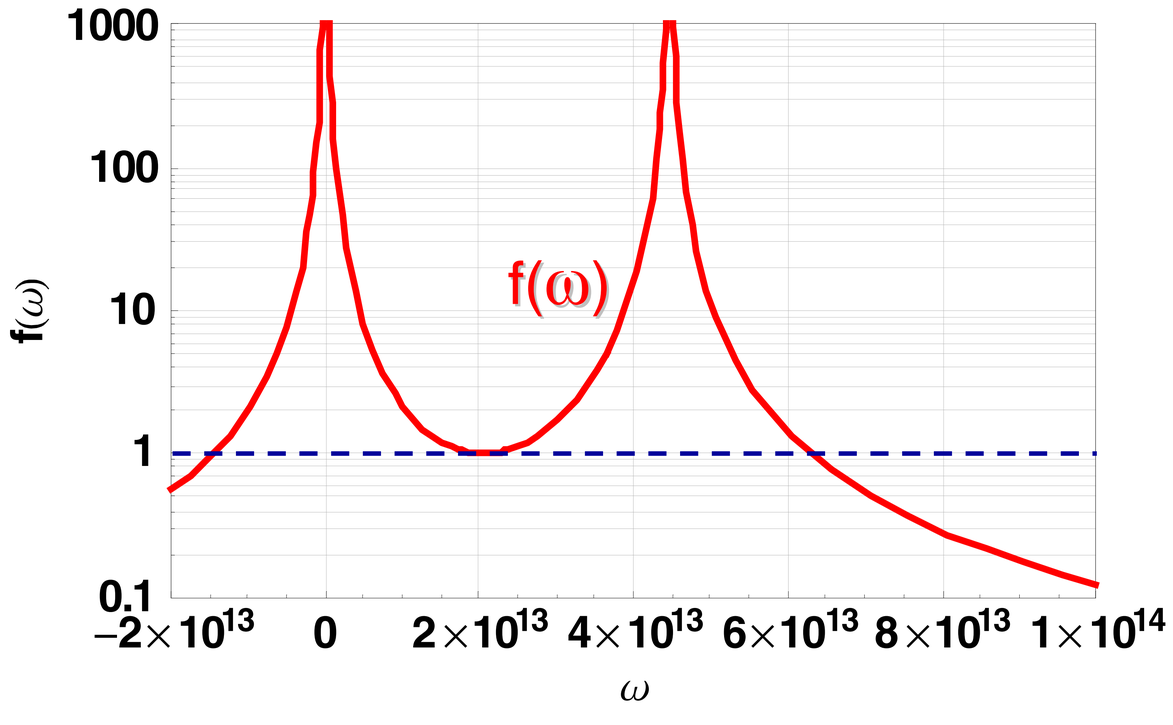


Dispersion Relation (for delta-function distributions)

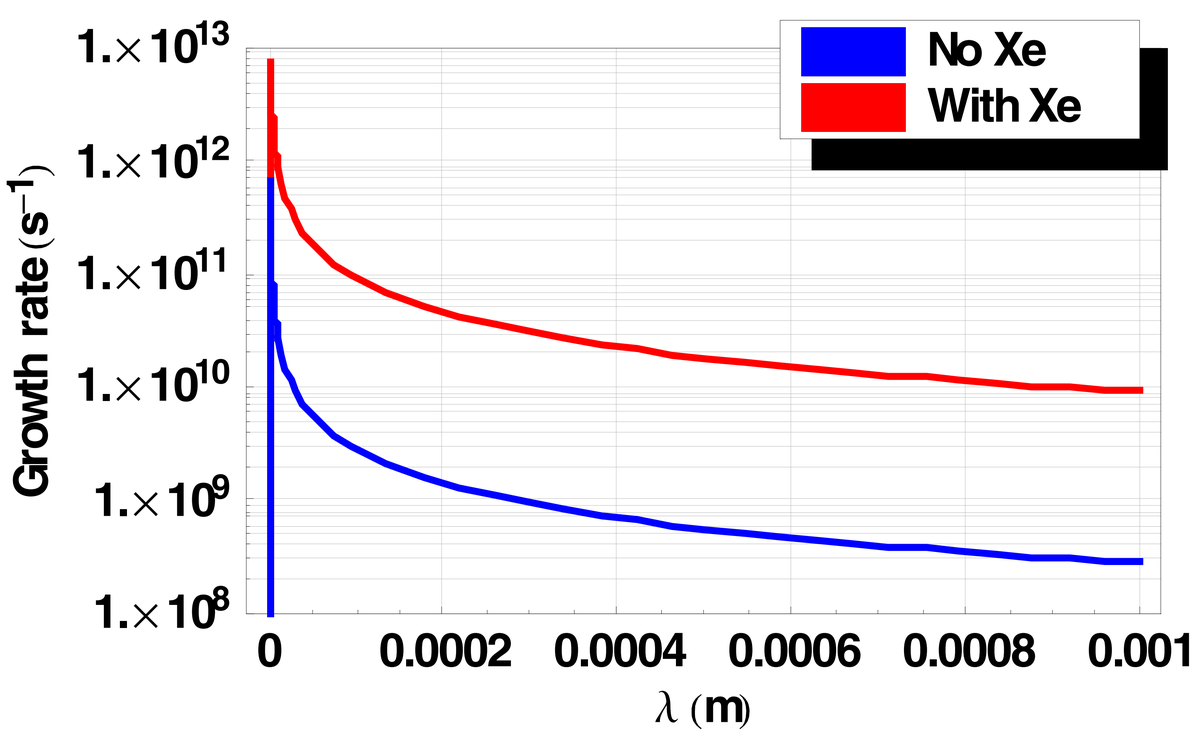
$$f(\omega) \equiv \frac{\omega_{pe}^2 + \omega_{Xe}^2}{\omega^2} + \frac{\omega_{peb}^2 + \omega_{pib}^2}{(\omega - \vec{k}\bullet\vec{v})^2} = 1$$

Minimum growth rate

$$\lambda_{\min} = 0.4\ \mu\text{m}$$



- *Simplified analysis*, using delta function distributions but including ions and electrons in both debris beam and background leads to instability with growth rate ~10^{13} s^{-1}.



- Perturbation must grow quickly to affect burst ions.
  - Burst is ~0.02 m thick and takes τ_s~1-10 ns to pass.
- Beam electrons shield beam ions from electrostatic perturbations on the beam Debye length scale (~10^{-7} m).
  - Minimum two-stream (delta-function) instability wavelength is λ~10^{-6} m.
  - Two-stream instability, therefore, occurs mainly between beam and background *electrons*.
- Ion-electron collision frequency in the beam is ν_{ie}~2x10^8 s^{-1}, so $\nu_{ie}\tau_s$<1 and the electrons do not have time to transmit the instability.
- Dissipative effects should reduce the growth rate, for example:
  - Landau damping, and
  - Non-chromatic ion velocities in the burst.

Conclusion:

Neglected Physics Effects Should Strongly Reduce the Instability, Probably Stabilizing It

- Caveat: definitive calculations are very complicated!