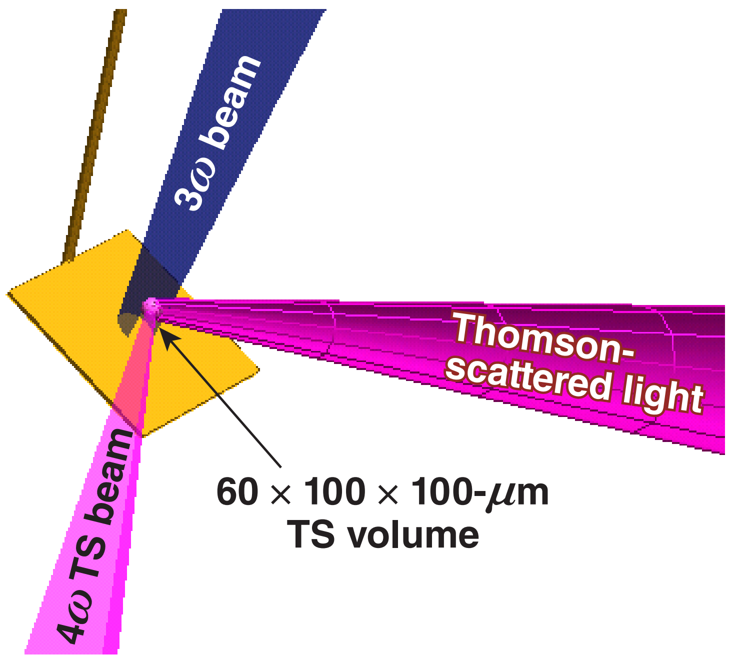
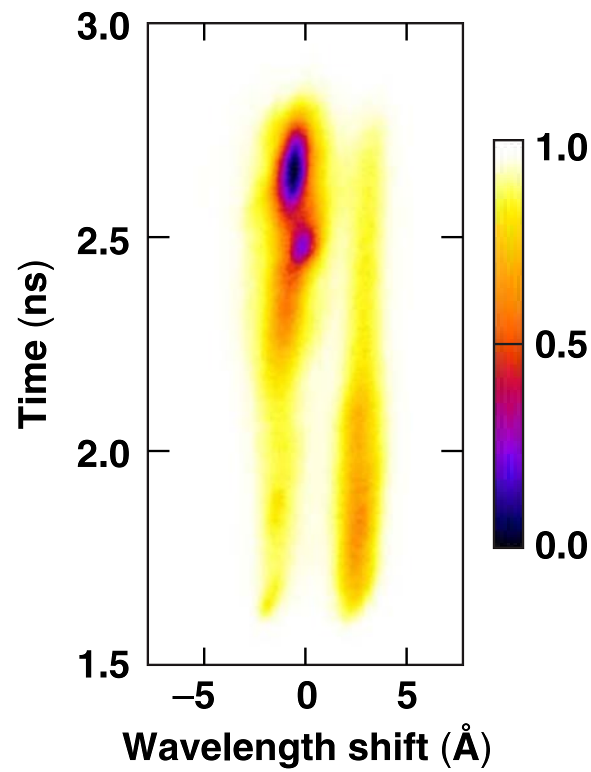
Ion-Acoustic-Wave Instability from Laser-Driven Return Currents





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Summary

An ion-acoustic-wave instability is observed for large ZT_e/T_i (i.e., weak ion Landau damping)

- The instability is enhanced when the target is cooling
- The instability saturates with signatures of trapping
- Weakly ion damped systems ($ZT_e/T_i > 30$) are susceptible to enhanced ion fluctuations
- This instability has implications for laser–plasma instabilities (enhanced T_i) and laser-beam absorption (turbulence)

The return current instability produces lower LPI thresholds and higher laser-beam absorption.

Collaborators

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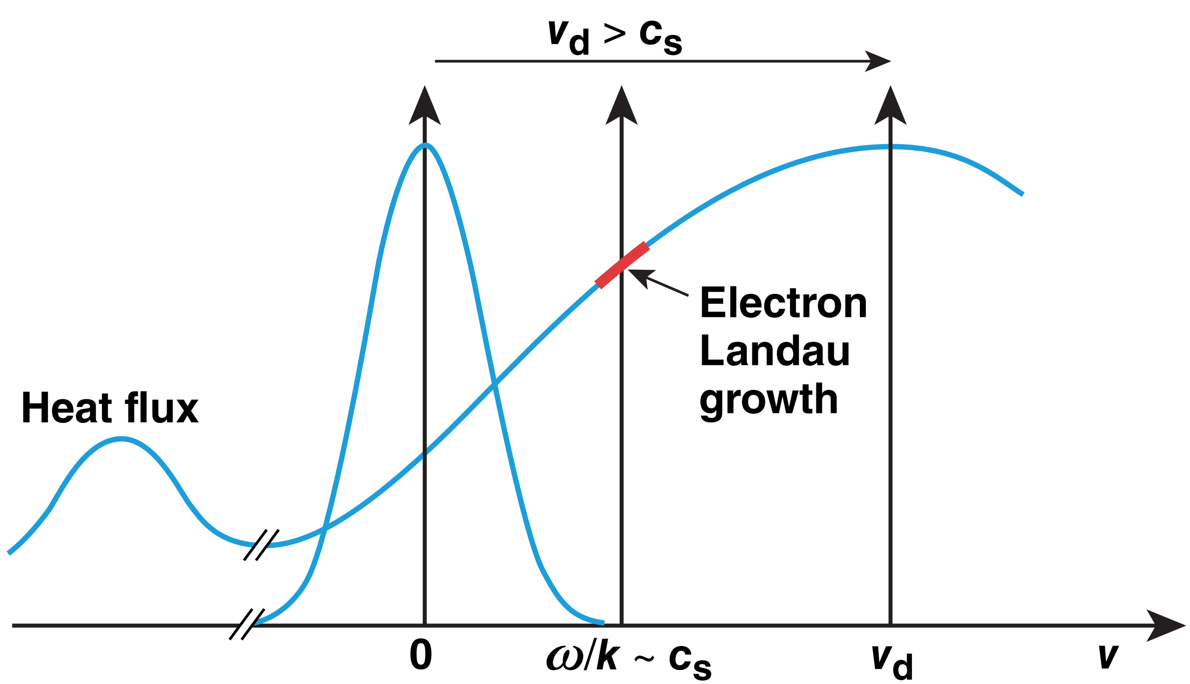
Ion-acoustic waves become unstable when the drift velocity exceeds the sound speed

- Heat is carried by "fast" electrons
- The relative drift between the electrons and ions maintains a quasi-neutral plasma
- When the drift exceeds the ion-acoustic phase velocity, electrons enhance the wave (electron Landau growth)
- If the Landau growth rate is larger than the ion Landau damping, the waves are unstable



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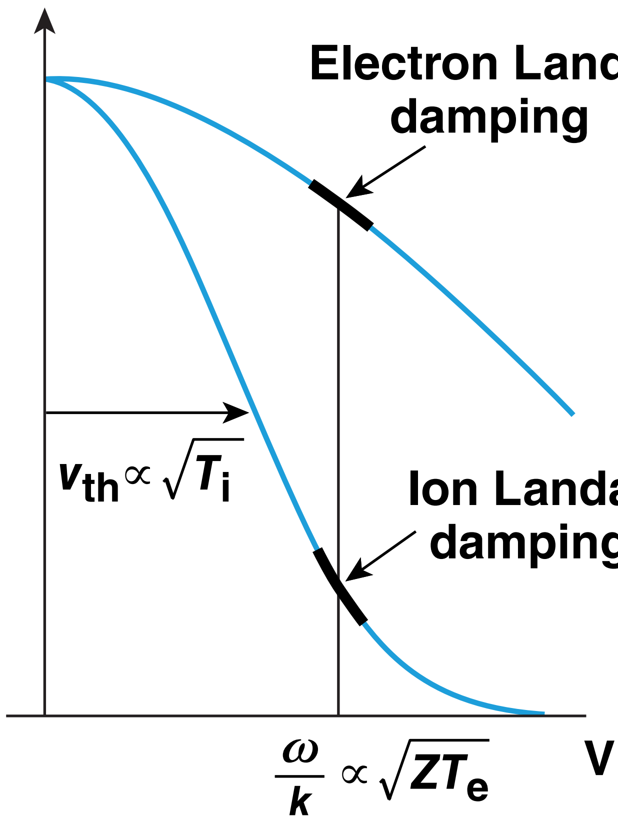
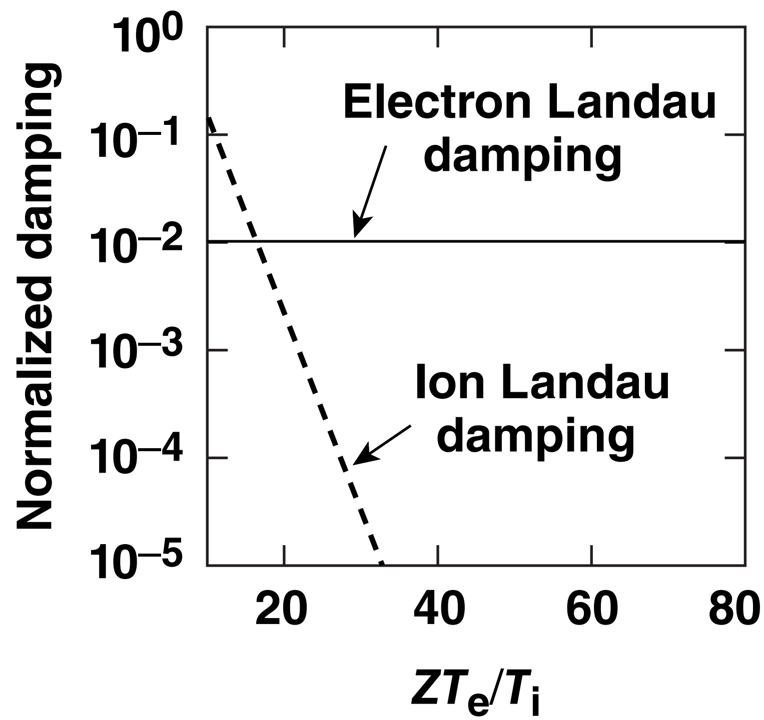
The amplitude of the scattered light is a function of the electron and ion Landau damping



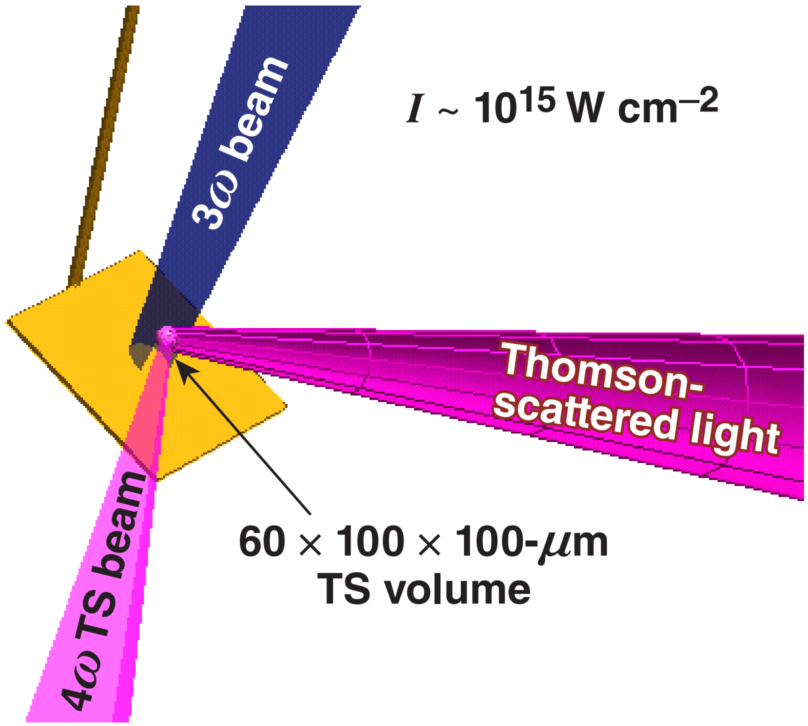


The ion Landau damping is negligible for $ZT_e/T_i > 30$, and the ion-wave amplitude is governed primarily by the electron-distribution function.

Experimental Setup

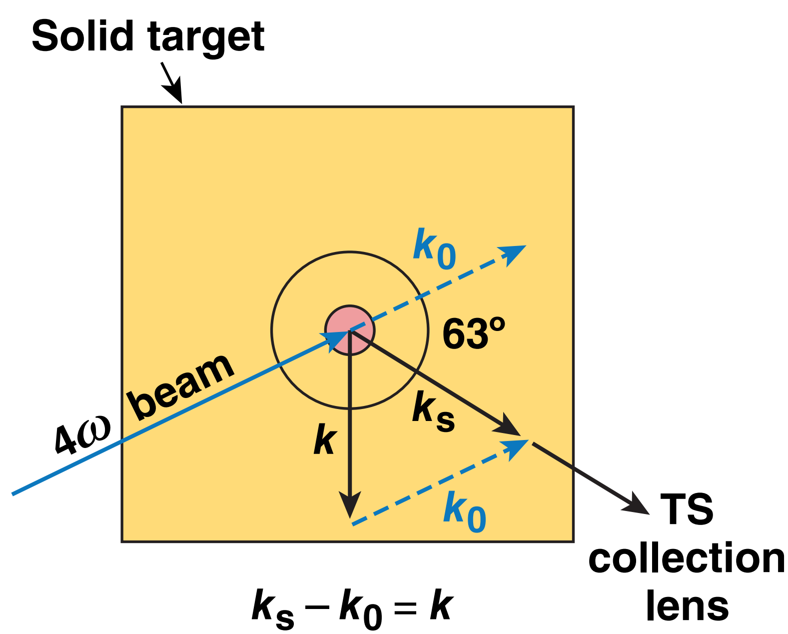
The ion-wave damping was varied by changing the target material (CH, V, Ag, Au)

The targets are heated by 1-, 2-, or 3-ns-long laser pulses



Thomson-scattering is measured 400 μm from the target surface

The 4ω beam and the collection direction are in the plane of the foil



$k_s - k_0 = k$

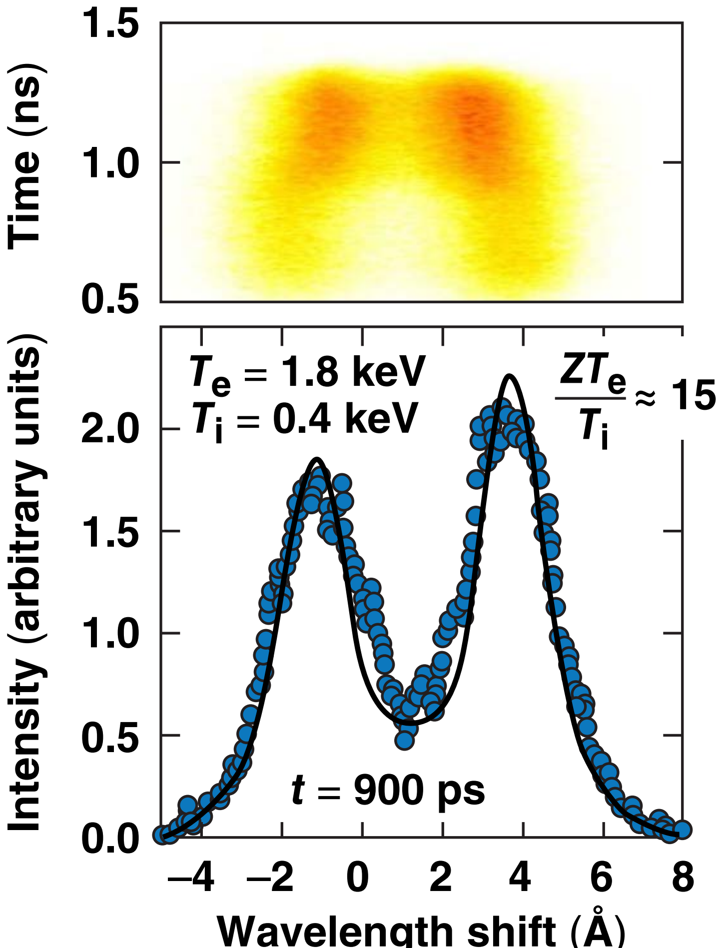
$k = 1.0\ k_0$

The system probes waves that are propagating radially

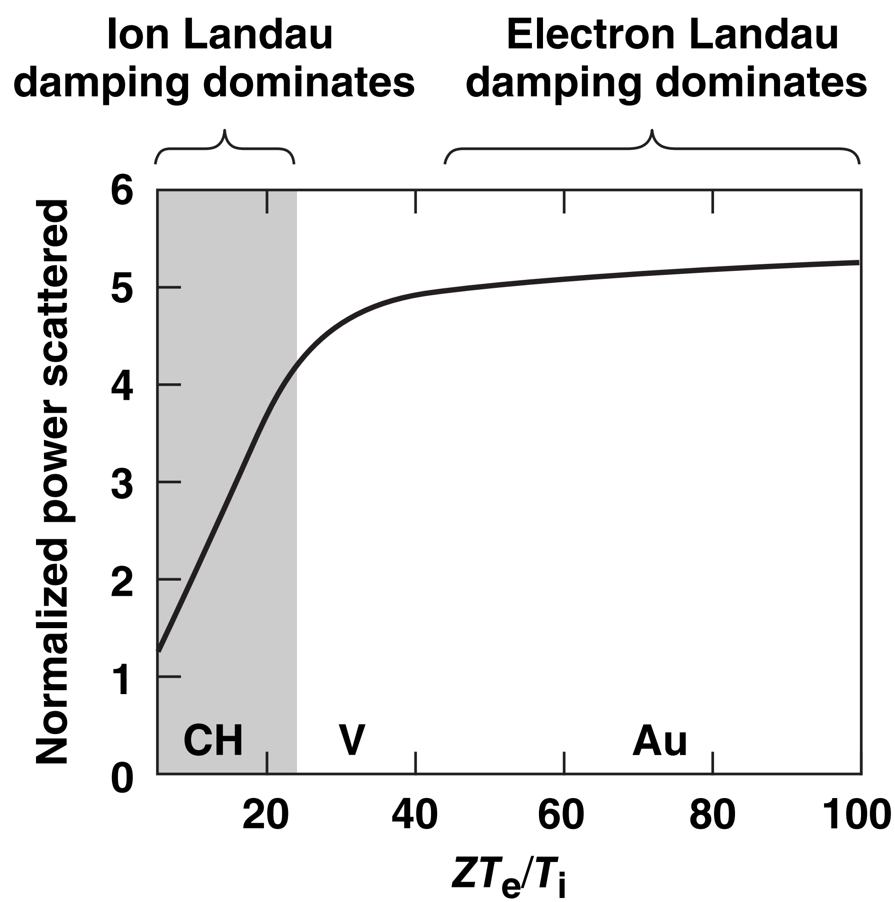
Plasma Characterization

Thomson-scattering measurements provide a direct measure of ZT_e/T_i and the amplitude of the ion-acoutic waves

Scattering from the ion-acoustic waves provides a measure of ZT_e, T_i



The amplitude of the scattered power is determined by Landau damping



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The ion-acoustic waves propagating to the center of the plasma are measured to be unstable in high-*Z* (Au) plasmas

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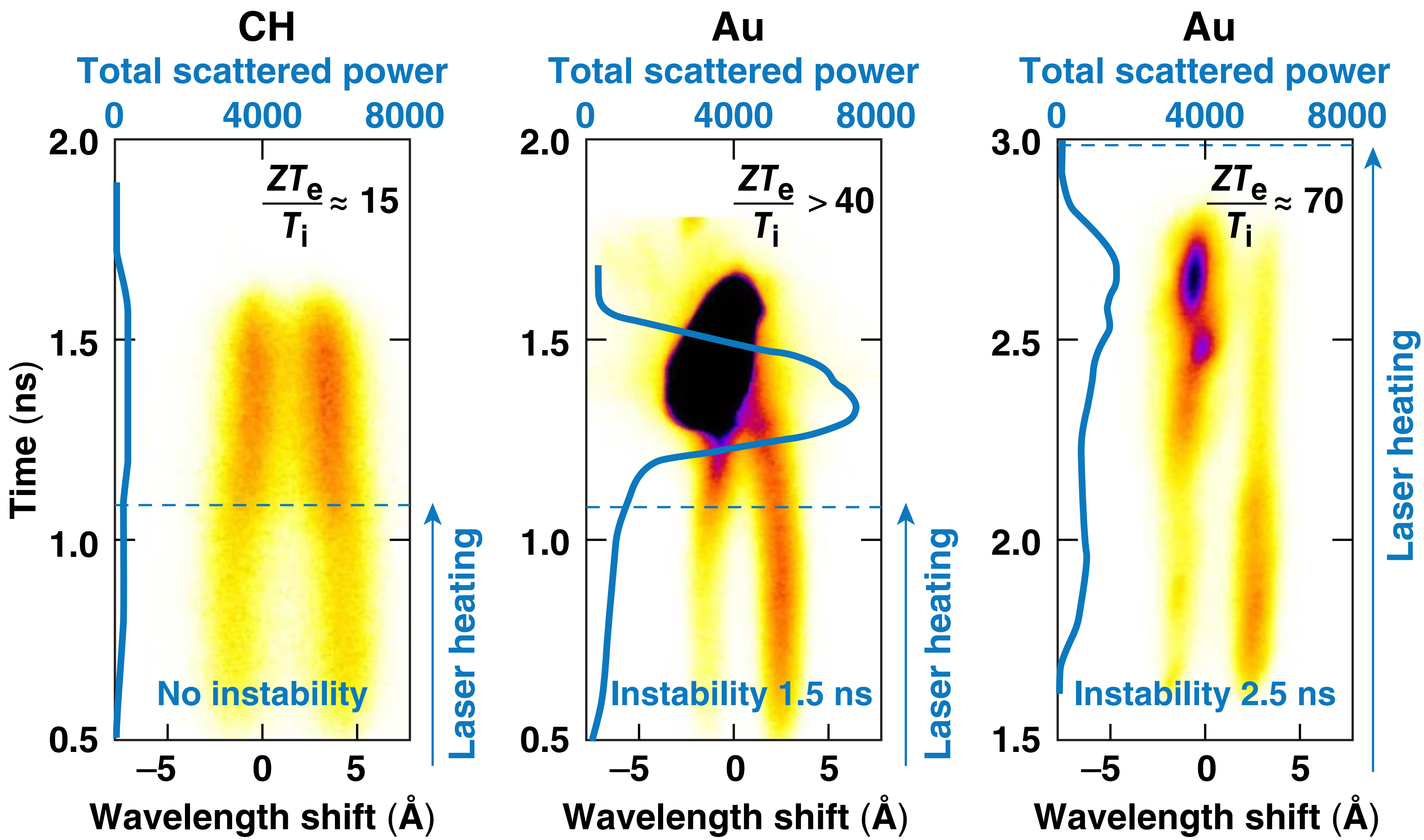
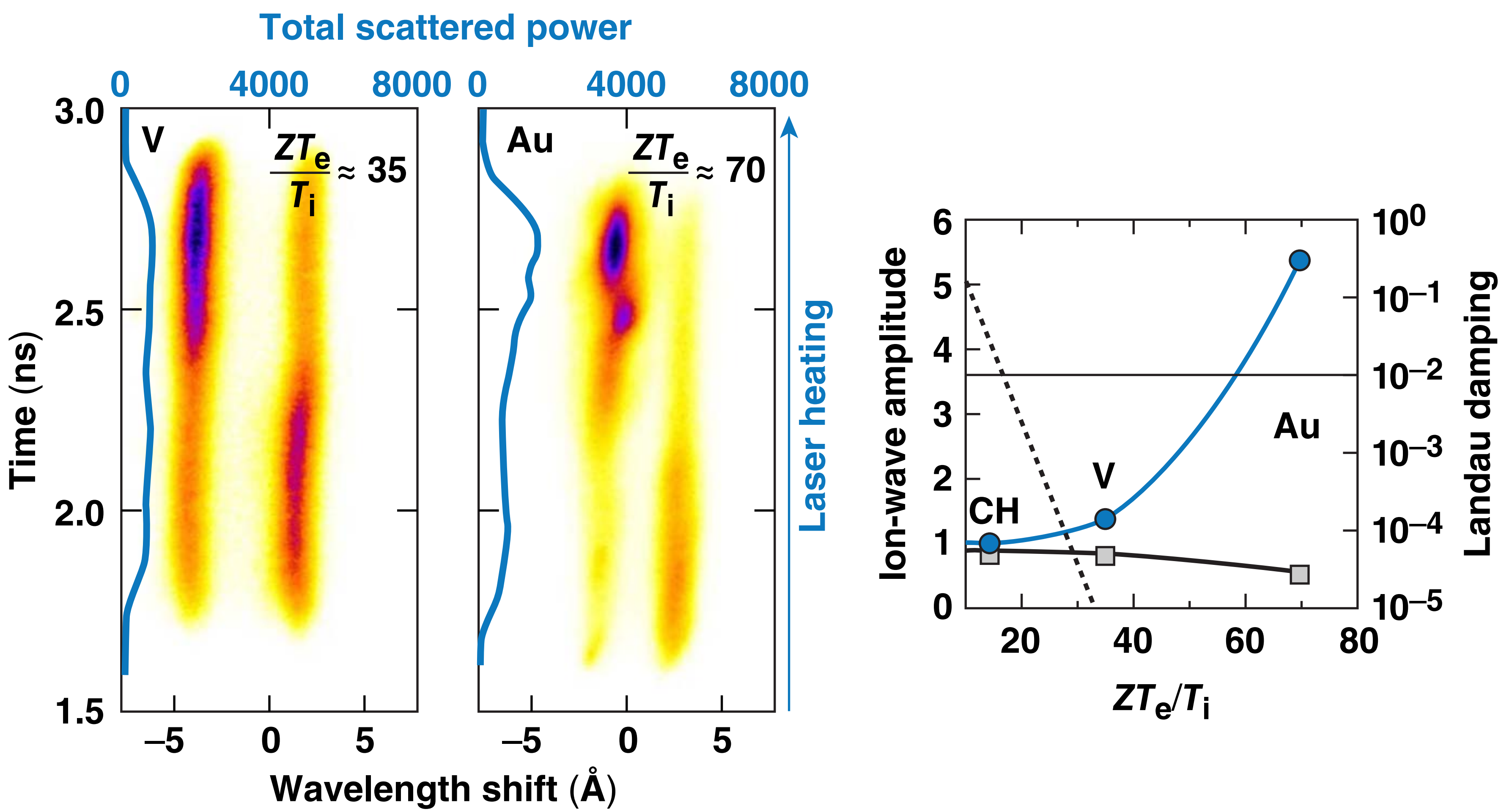


The instability is enhanced when the plasma is cooling.

For ZT_e/T_i < 40, the ion-acoustic waves are damped sufficiently by the ions to remain stable



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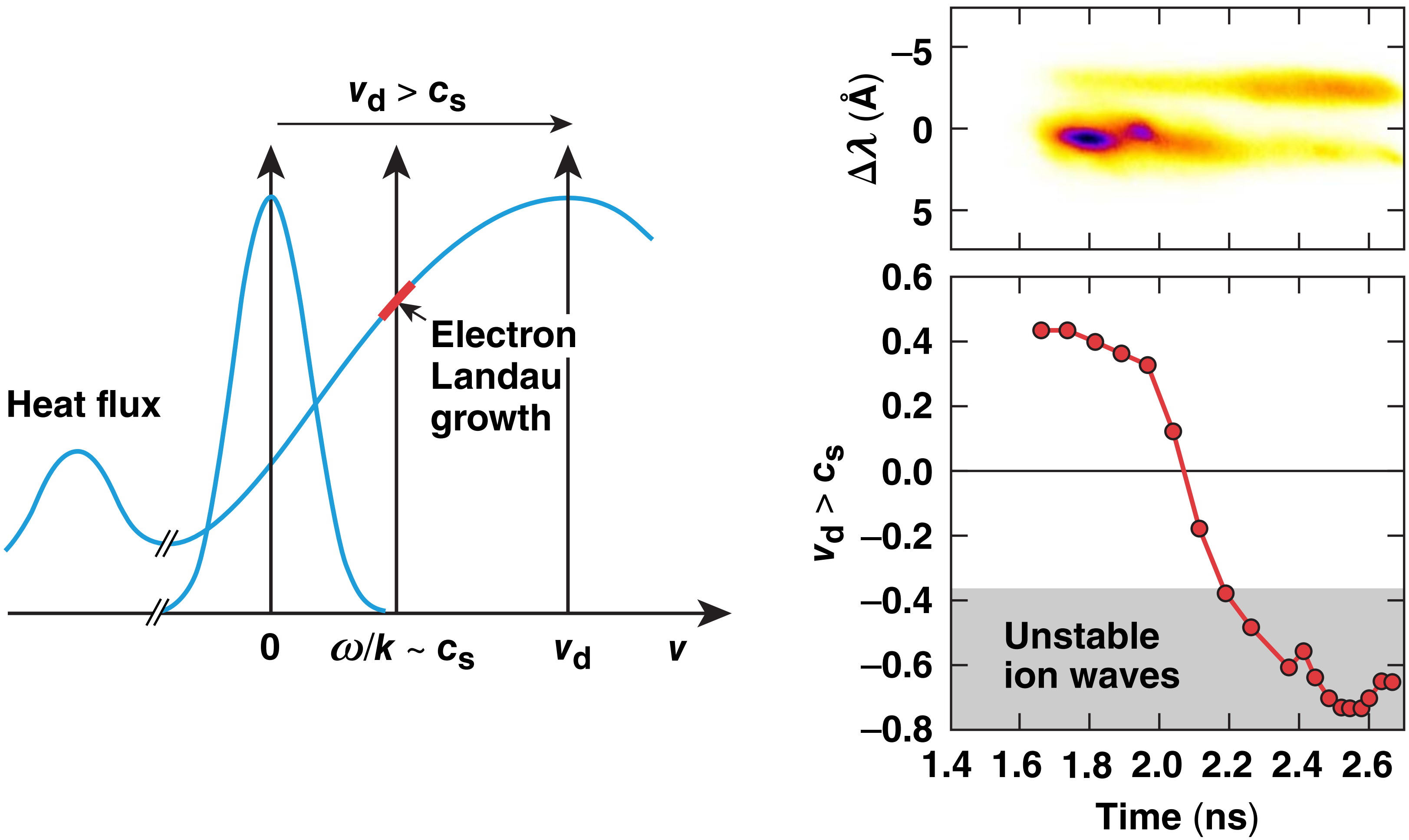
Instability

This instability is likely driven by the return current (return-current instability)



When the return current shifts the peak of the electron-distribution function beyond the sound speed, the electrons "drive" the wave.

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Summary/Conclusions

An ion-acoustic-wave instability is observed for large ZT_e/T_i (i.e., weak ion Landau damping)

- The instability is enhanced when the target is cooling
- The instability saturates with signatures of trapping
- Weakly ion damped systems ($ZT_e/T_i > 30$) are susceptible to enhanced ion fluctuations
- This instability has implications for laser–plasma instabilities (enhanced T_i) and laser-beam absorption (turbulence)

The return current instability produces lower LPI thresholds and higher laser-beam absorption.

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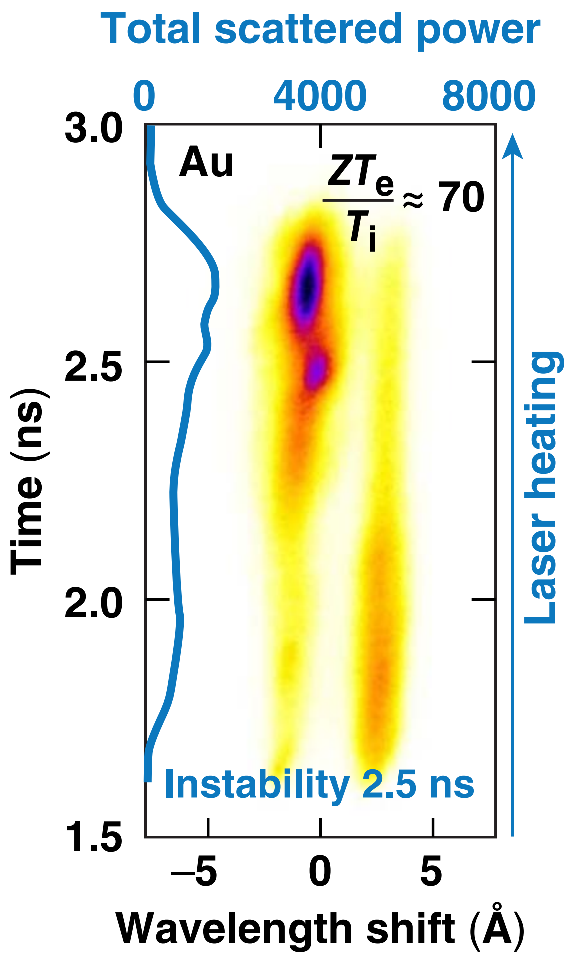
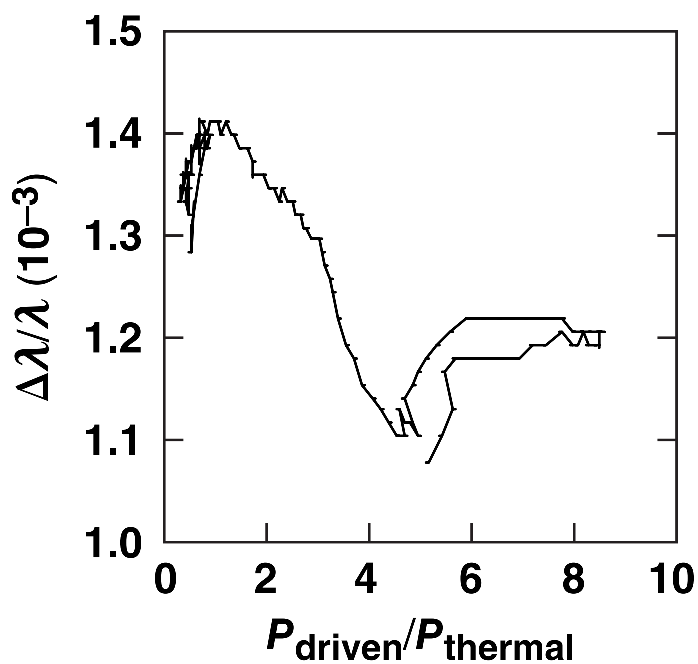
The frequency shift in the driven ion-acoustic wave is consistent with trapping





The ion temperature and laser-beam coupling are enhanced by the unstable ion-acoustic waves.

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At stable conditions, the drift velocity can be measured and compared with fluid simulations

$$q = -\beta\, T_e n_e \left[v_d + \nu_T \lambda_e \alpha \nabla \ln(n_e)\right]$$