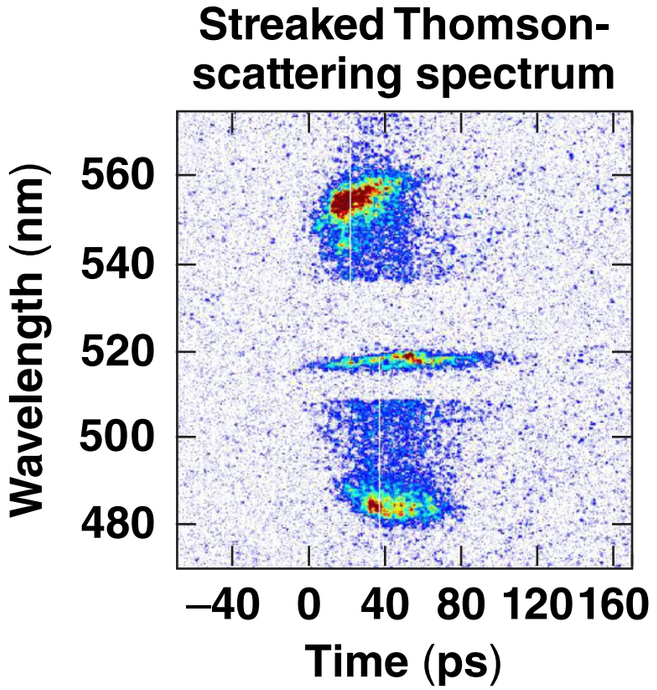
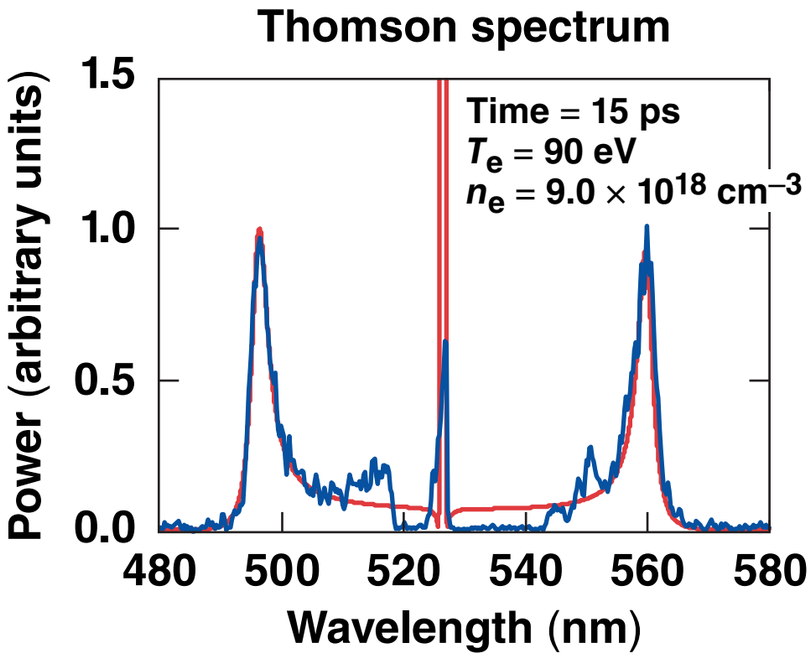
Picosecond Characterization of Underdense Plasmas for Studying Nonlinear Electron Plasma Wave Dynamics





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Summary

Time-resolved Thomson scattering was used to characterize the temperature and density of a low-density plasma on a picosecond time scale

- The electron temperature was measured to increase rapidly to 90 eV over the first 15 ps and continues to 100 eV by 50 ps
- Initial measurements of the stimulated Raman scattering (SRS) backscatter spectrum have shown evidence of nonlinear electron plasma waves (EPW's) at high intensities
- Dynamic Thomson scattering will be used to directly probe the amplitude and frequency of the EPW's
  - trapping-induced frequency shifts
  - wavebreaking threshold
  - Landau damping

Collaborators

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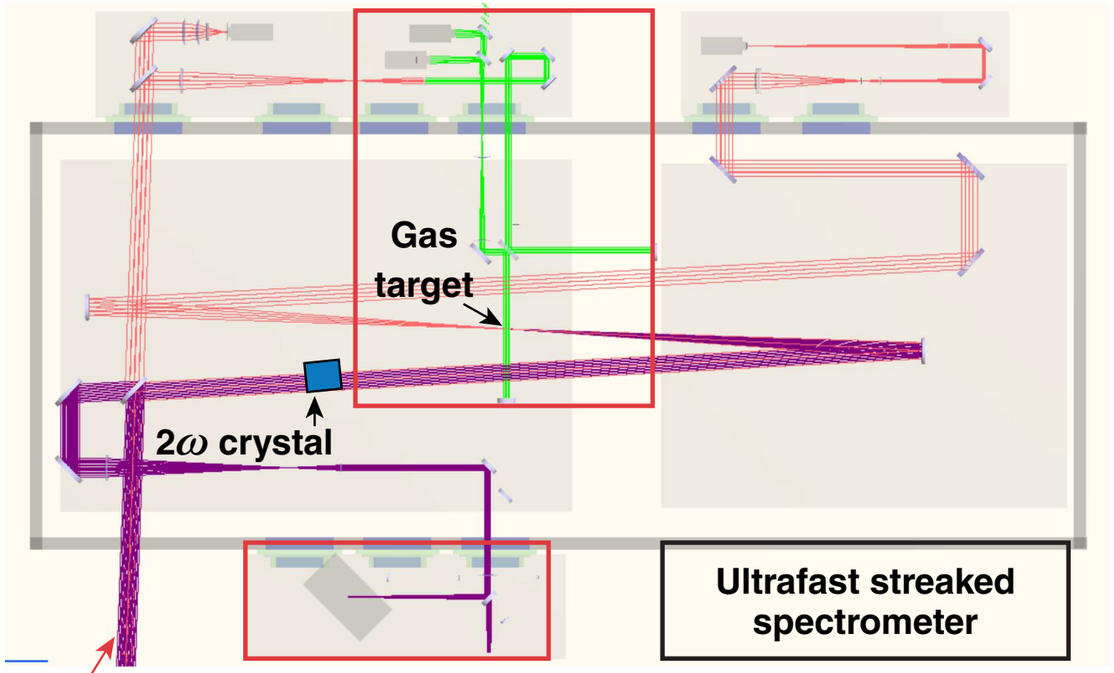
Initial experiments are focusing on characterizing the plasma and measuring SRS backscatter dynamics in the nonlinear regime



- Pump
  - λ_{cen} = 1053 nm
  - E_{max} = 50 J
  - Δt = 1 to 100 ps
- Thomson-scattering probe
  - λ_{probe} = 527 nm
  - ~1 J

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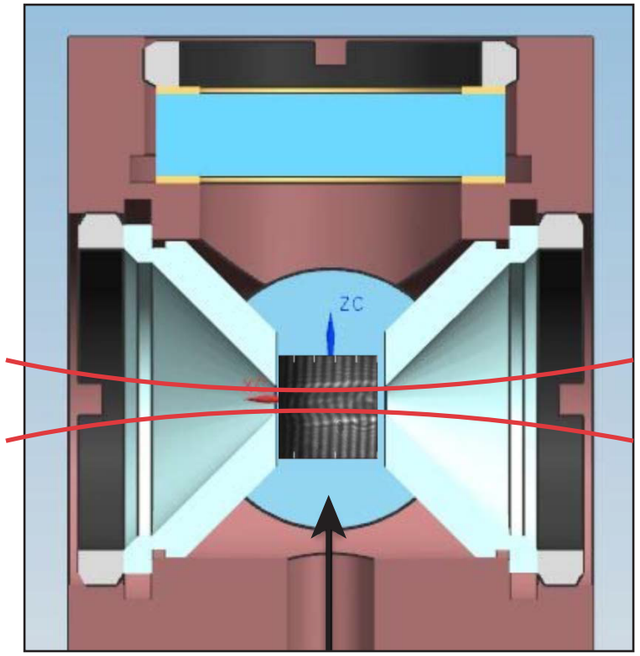
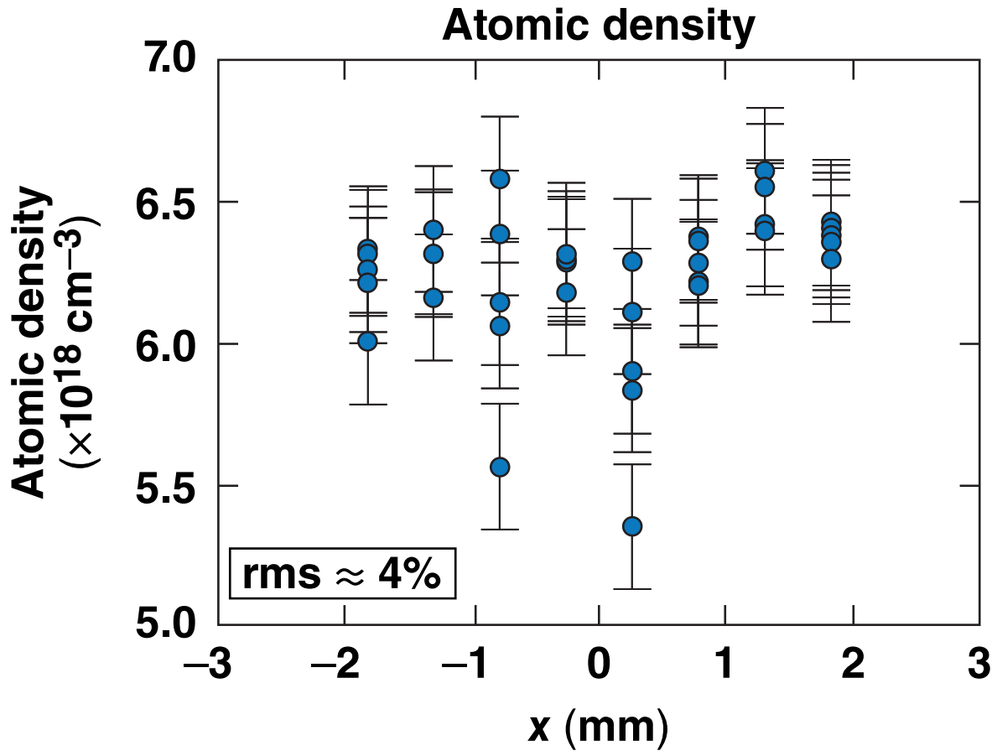
An H_2 gas cell was used to create a 4-mm-long homogenous plasma and characterized using interferometry

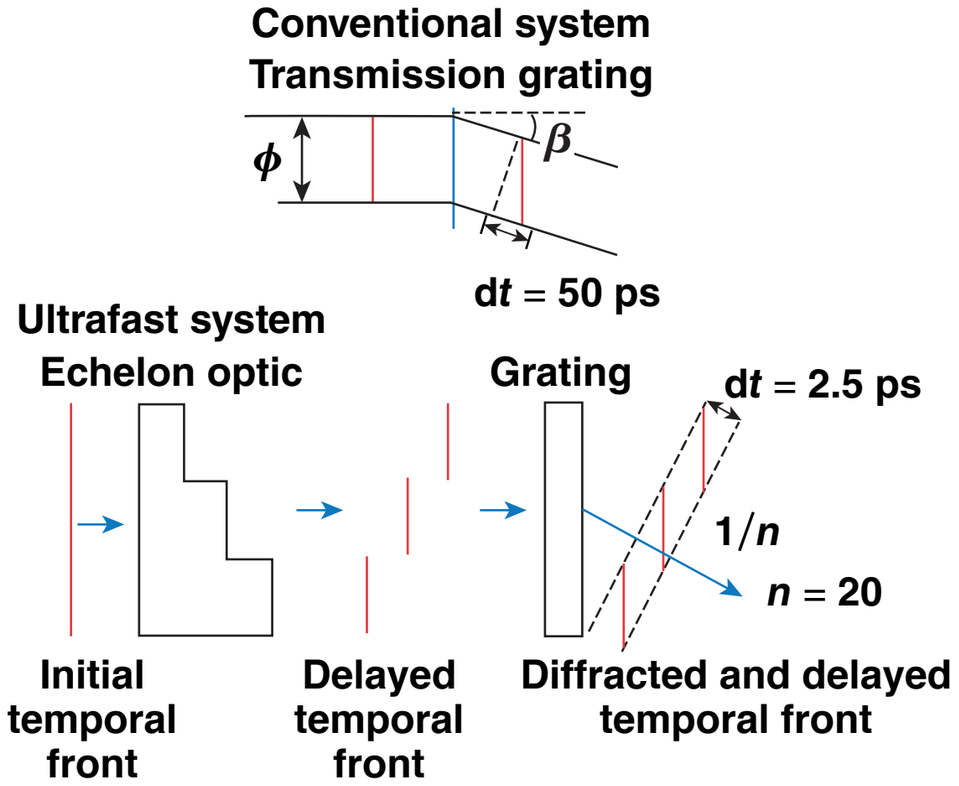


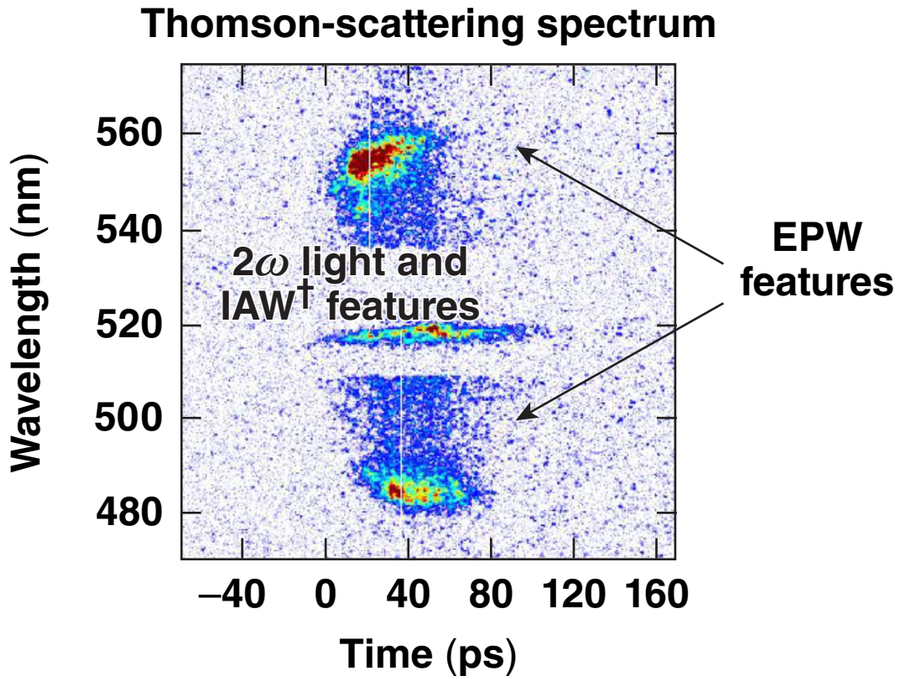


Interferometry indicates a neutral gas uniformity less than 4% rms.

rms: root mean square

A novel high-throughput (*f*/5), ultrafast (ps), Thomson-scattering system* was used to measure the evolution of the plasma conditions

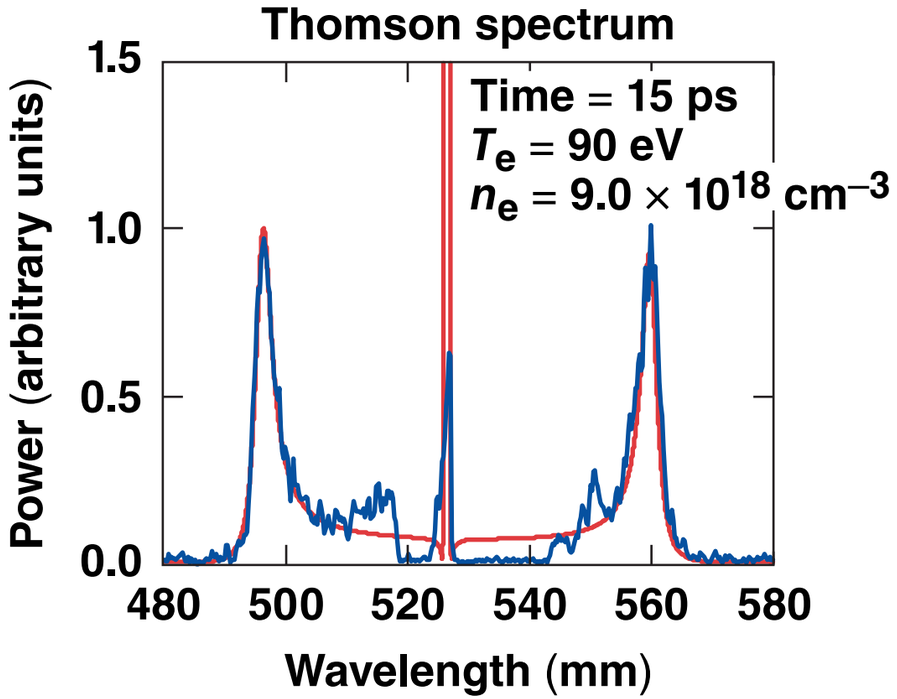


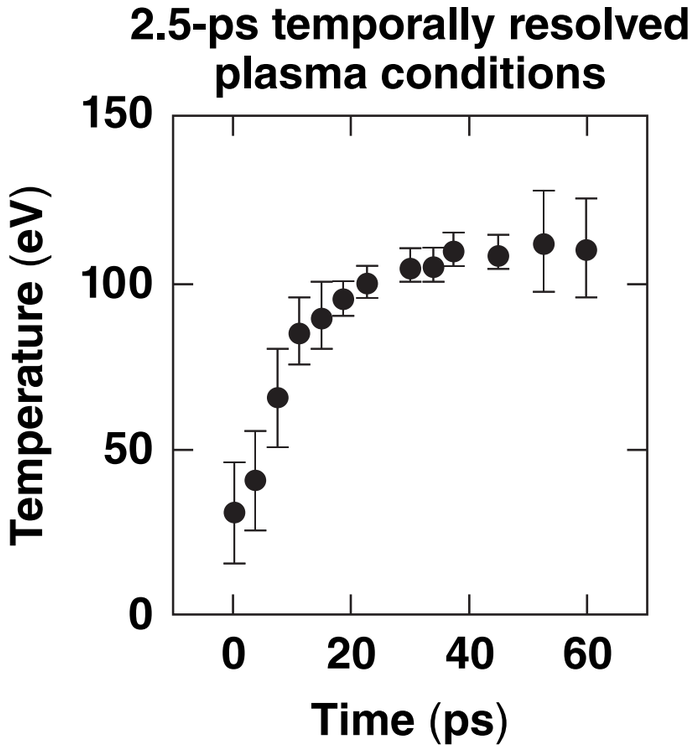


This system is >20× faster than an equivalent (*f*/5) conventional streaked spectrometer diagnostic.

*J. Katz *et al.*, Rev. Sci. Instrum. 87, 11E535 (2016).
†IAW: ion-acoustic wave

Thermal Thomson scattering was used to measure the electron temperature and density





The electron temperature was measured to increase rapidly in 15 ps to 90 eV.

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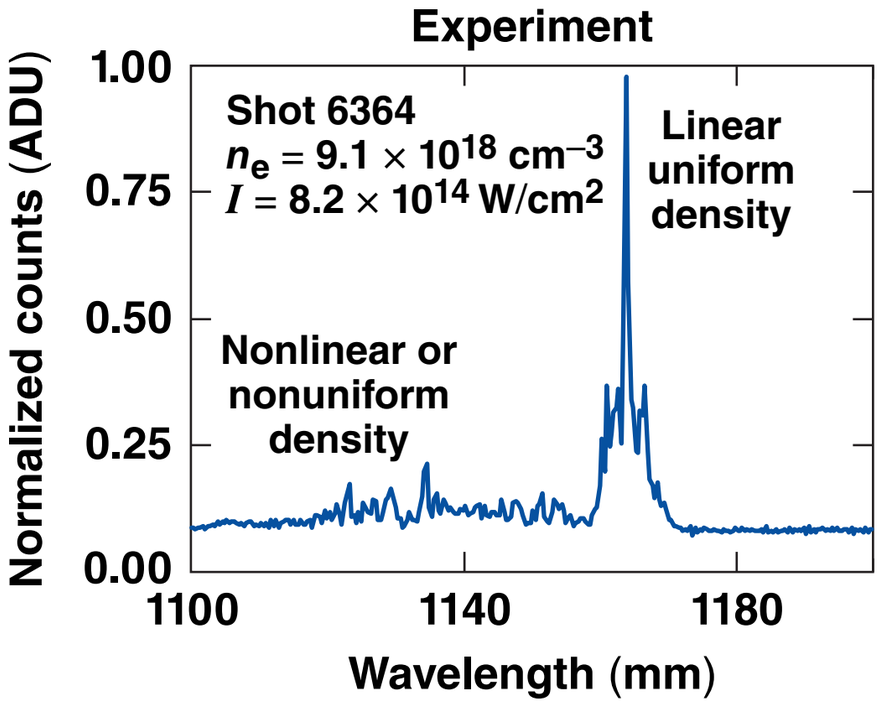
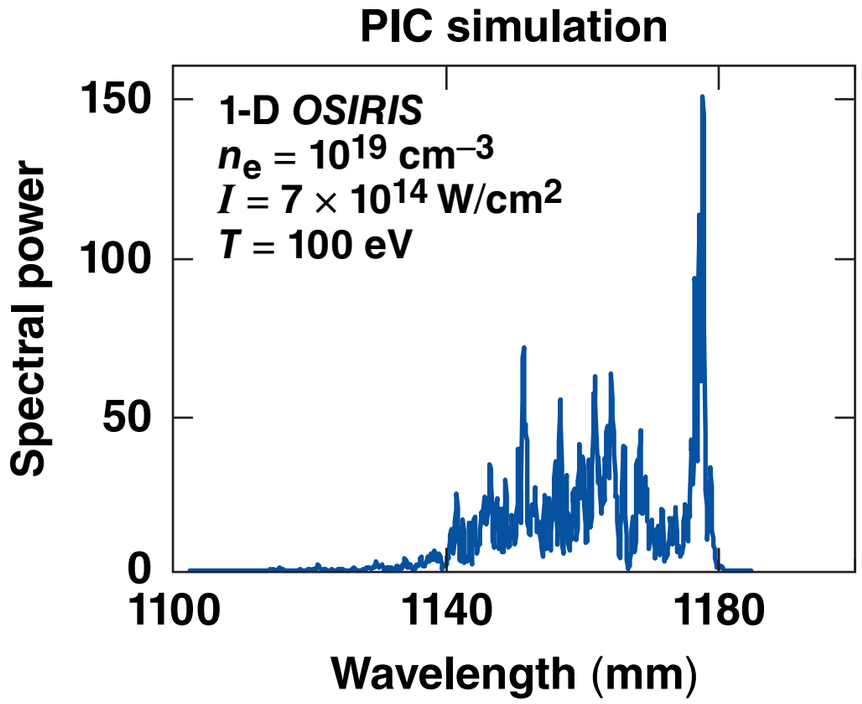
The backscatter spectrum suggests nonlinear physics are involved in high-intensity short-pulse experiments





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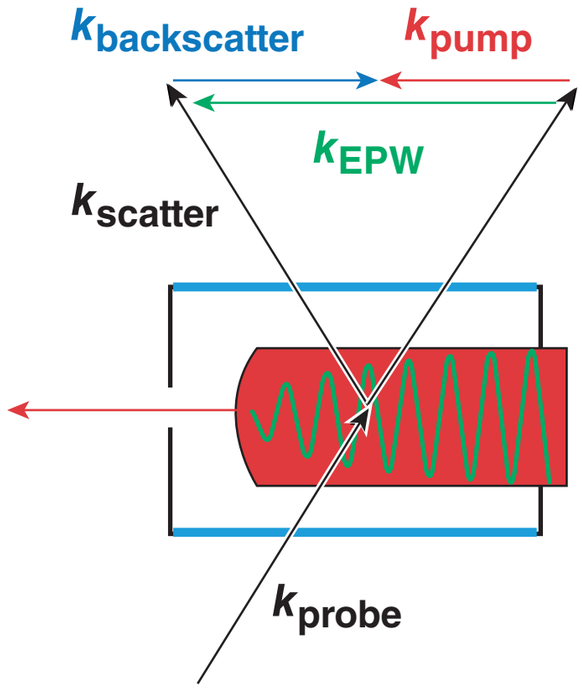
A dynamic Thomson-scattering diagnostic will measure the frequency and amplitude of driven electron plasma waves



$$k_{scatter} = k_{probe} + k_{EPW}$$
$$\omega_{scatter} = \omega_{probe} + \omega_{EPW}$$
$$\omega_{EPW} = \omega_p \pm \Delta\omega_{NL}$$

Diffraction efficiency η for linear plasma waves

$$\eta = \sin^2 \frac{\pi L_p \dfrac{\Delta n_e}{2n_c}}{\sqrt{\lambda_{probe}\lambda_{scatter}\cos\theta}}$$

These experiments will quantify the effects of trapping ($\Delta\omega_{NL}$) and the wavebreaking threshold in a well-characterized plasma.

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Summary/Conclusions

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