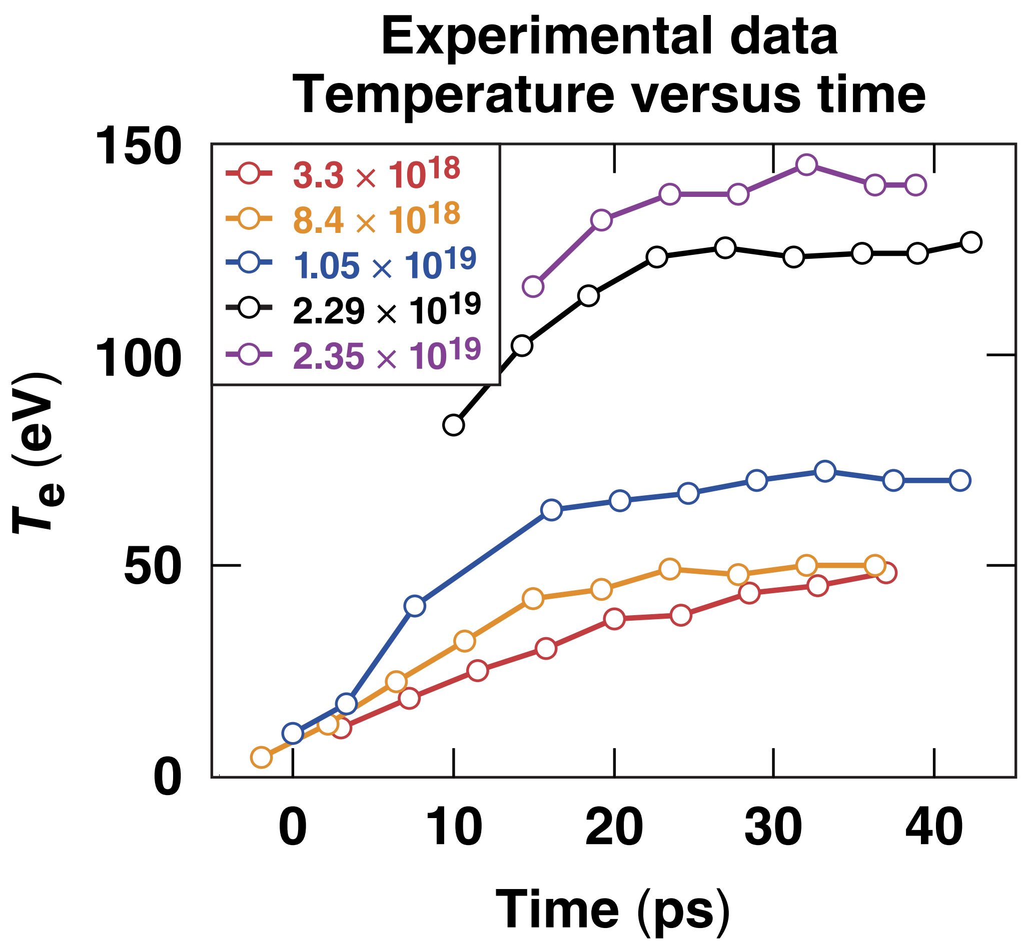
Picosecond Thermal Dynamics in an Underdense Plasma Measured with Thomson Scattering



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Summary

Time-resolved Thomson scattering shows that the temperature conditions for a Raman amplifier are highly dependent on plasma density

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- A pulse-front-tilt compensated streaked spectrometer was utilized for the first time to measure underdense plasma thermal dynamics
- The electron-heating rate and plateau temperature are found to increase with higher densities
- The electron temperature was observed to rise from an initial 5 eV to a plateau temperature in 23 ps

Collaborators

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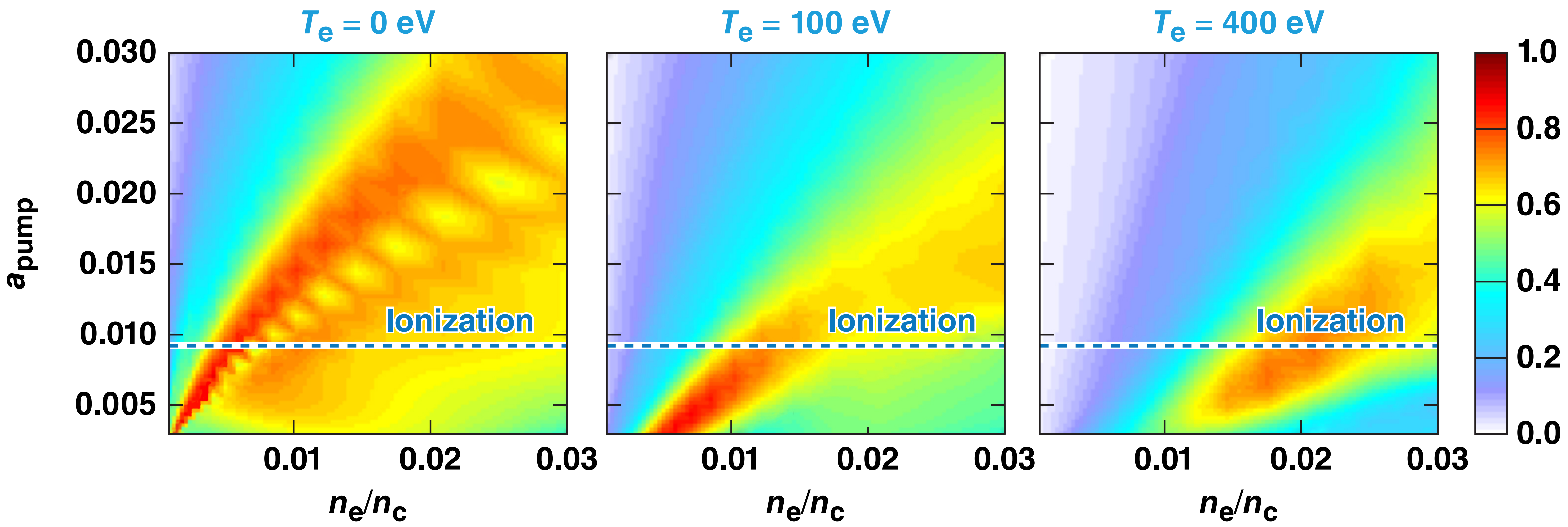
Motivation

Electron temperature introduces kinetic effects (wave breaking, particle trapping, Landau damping), which strongly reduce the efficiency of Raman amplification

OSIRIS simulations

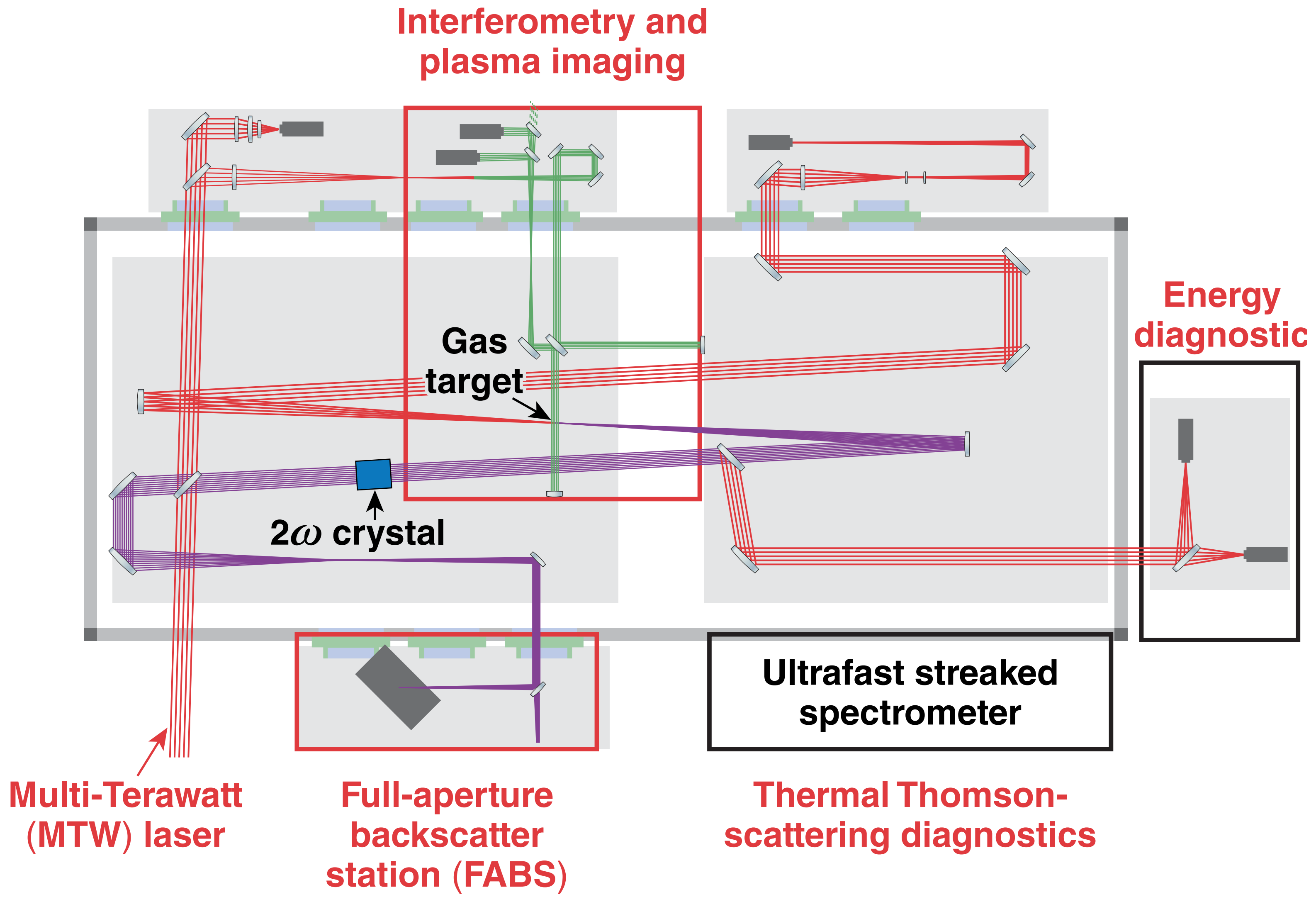
1-D, constant pump, constant density, seed meets nonlinear regime



Kinetic effects change the parameter regime for optimal efficiency in a Raman amplifier.

J. D. Sadler *et al.*, Phys. Rev. E 95, 053211 (2017).

An underdense plasma experimental system was constructed to make precise measurements of plasma temperature, nonlinear/driven plasma waves, and laser propagation



- Pump
  - λ = 1053 nm
  - E = 1.27 J
  - Δt = 55 ps
- Thomson-scattering probe
  - λ = 527 nm
  - E = 0.5 J
  - Δt = 40 ps

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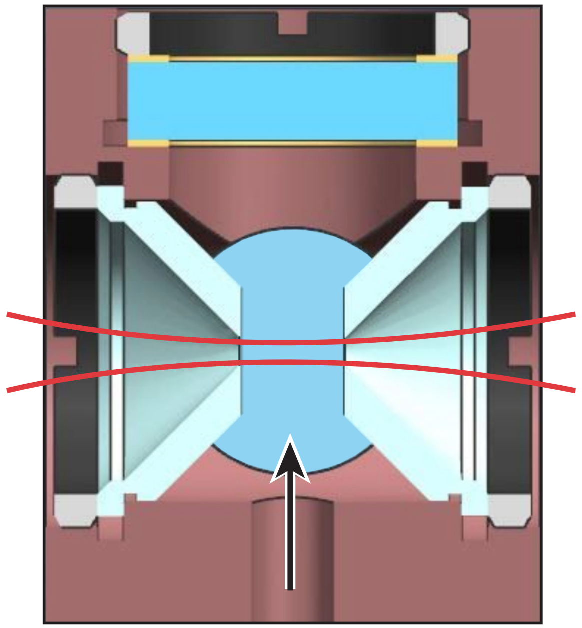
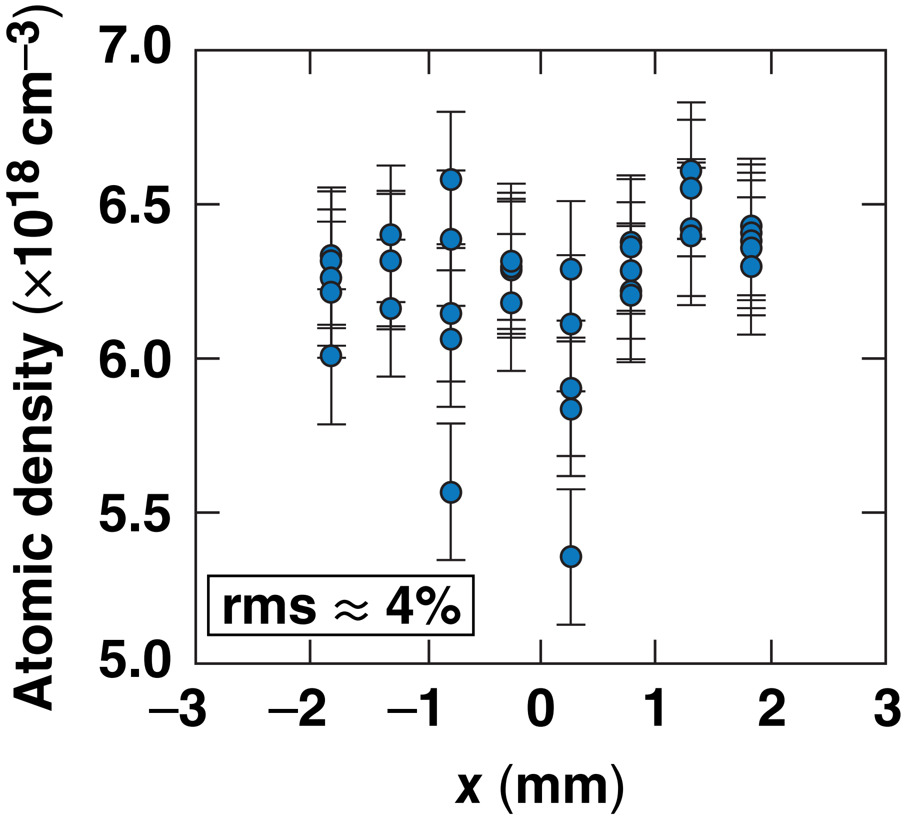
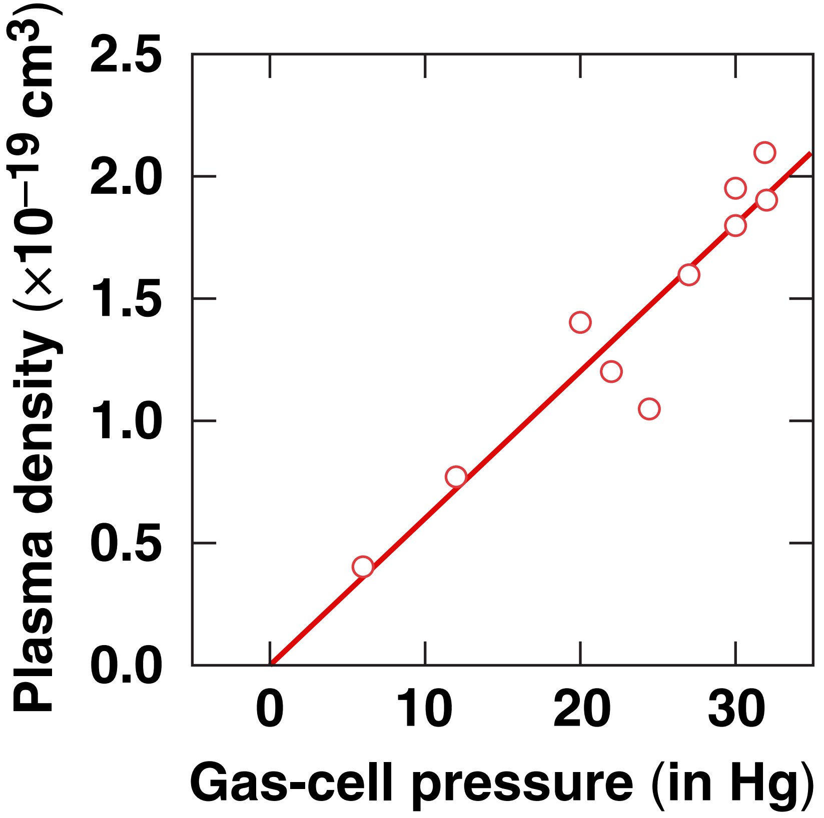
An H_2 gas cell was used to create a 4-mm-long homogenous plasma and characterized using interferometry and Thomson scattering







rms = root mean square

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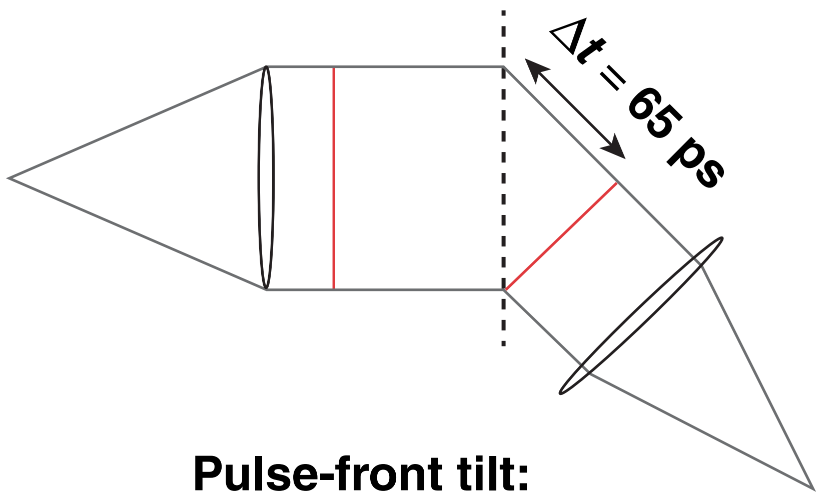
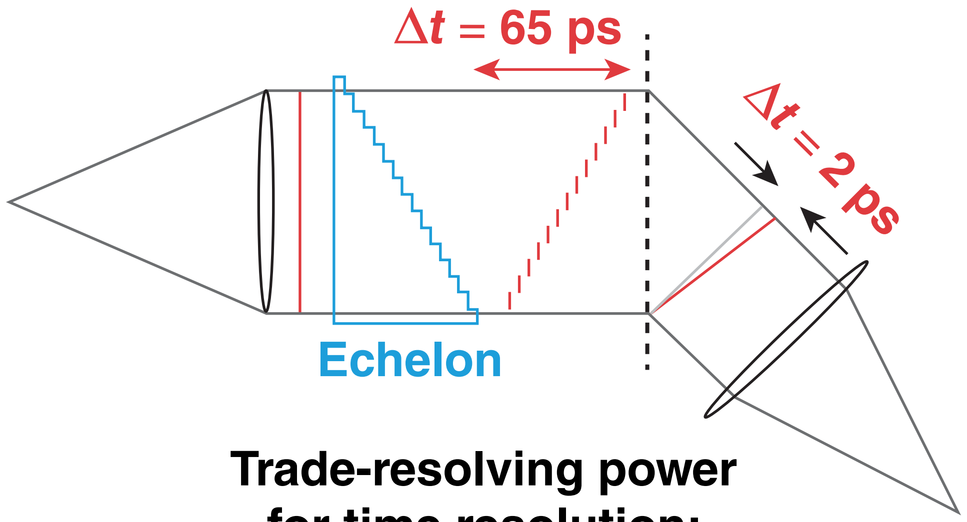
A novel high-throughput (*f*/5), ultrafast picosecond Thomson-scattering system* was required to measure the evolution of the plasma conditions





Pulse-front tilt:

$$\Delta t = \frac{N\lambda}{c}$$

Trade-resolving power for time resolution:

$$\Re = \frac{\lambda}{\Delta\lambda} = N = G \times d$$

	Resolving Power	G (ll/mm)	dx/dλ (mm/nm)	*d* (mm)	*f*#	Δt (ps)
Conventional	20,000 (0.025 nm)	300	0.125	65	5	65
Ultrafast	600 (1 nm)	300	0.125	2	5	2

*J. Katz *et al.*, Rev. Sci. Instrum. 87, 11E535 (2016).

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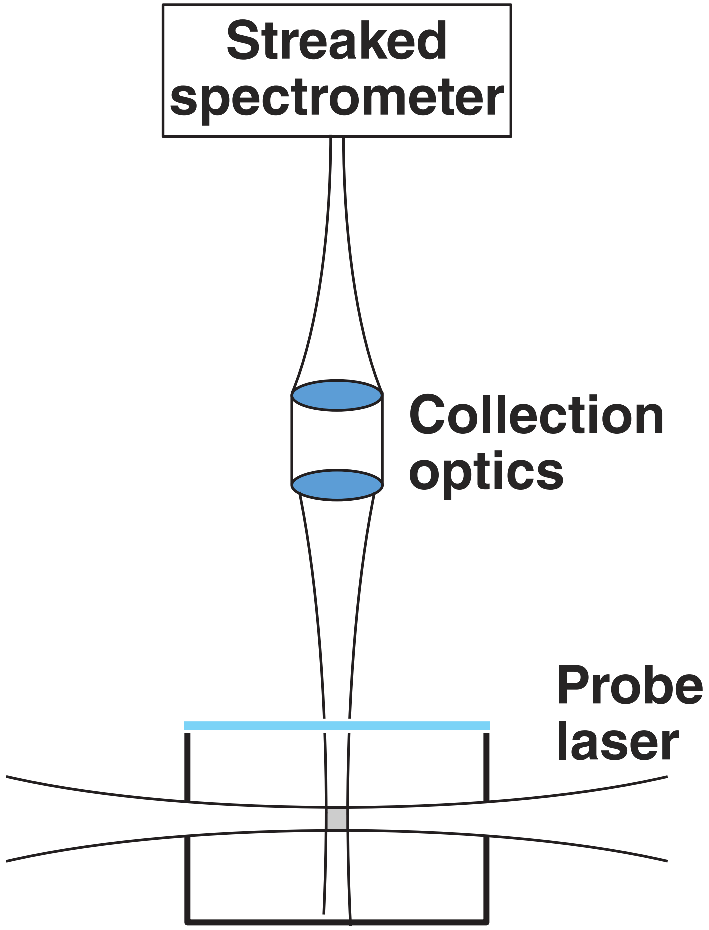
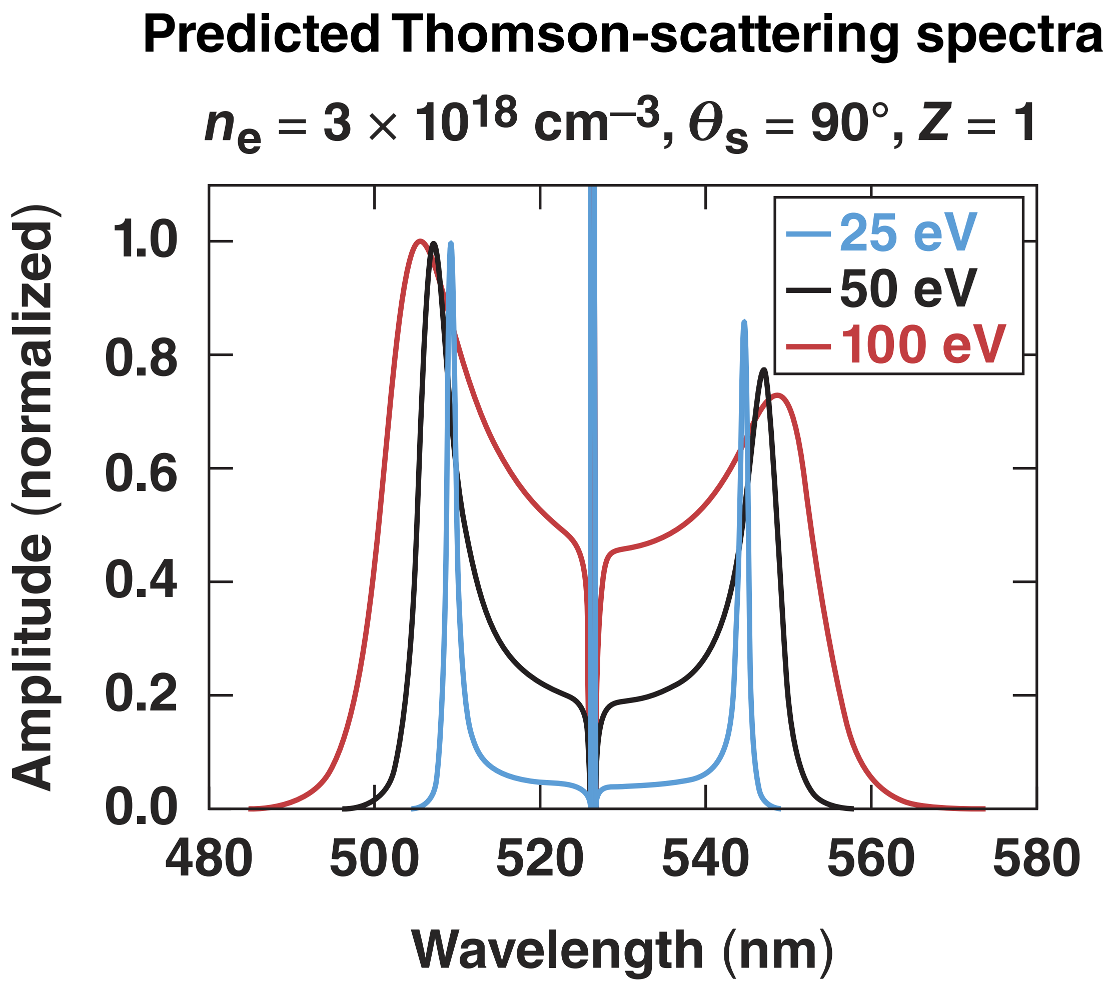
The electron temperature and density can be determined by scattering from thermal electron plasma waves





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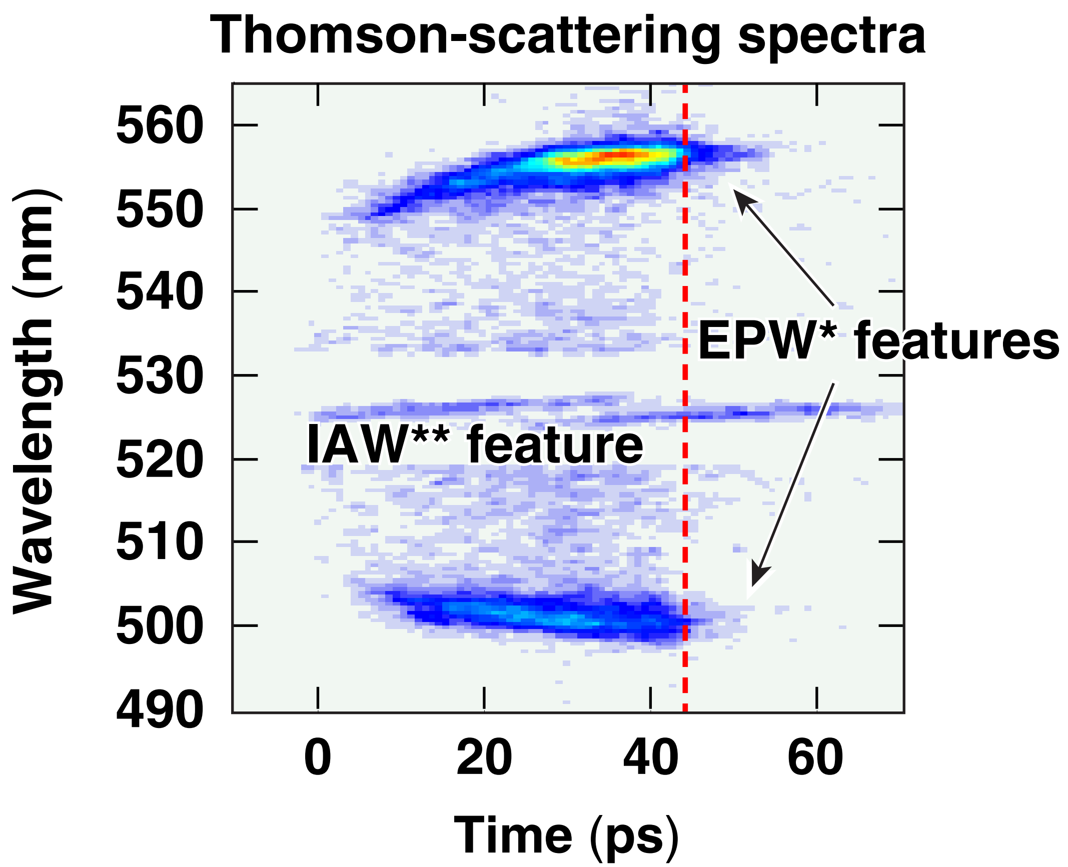
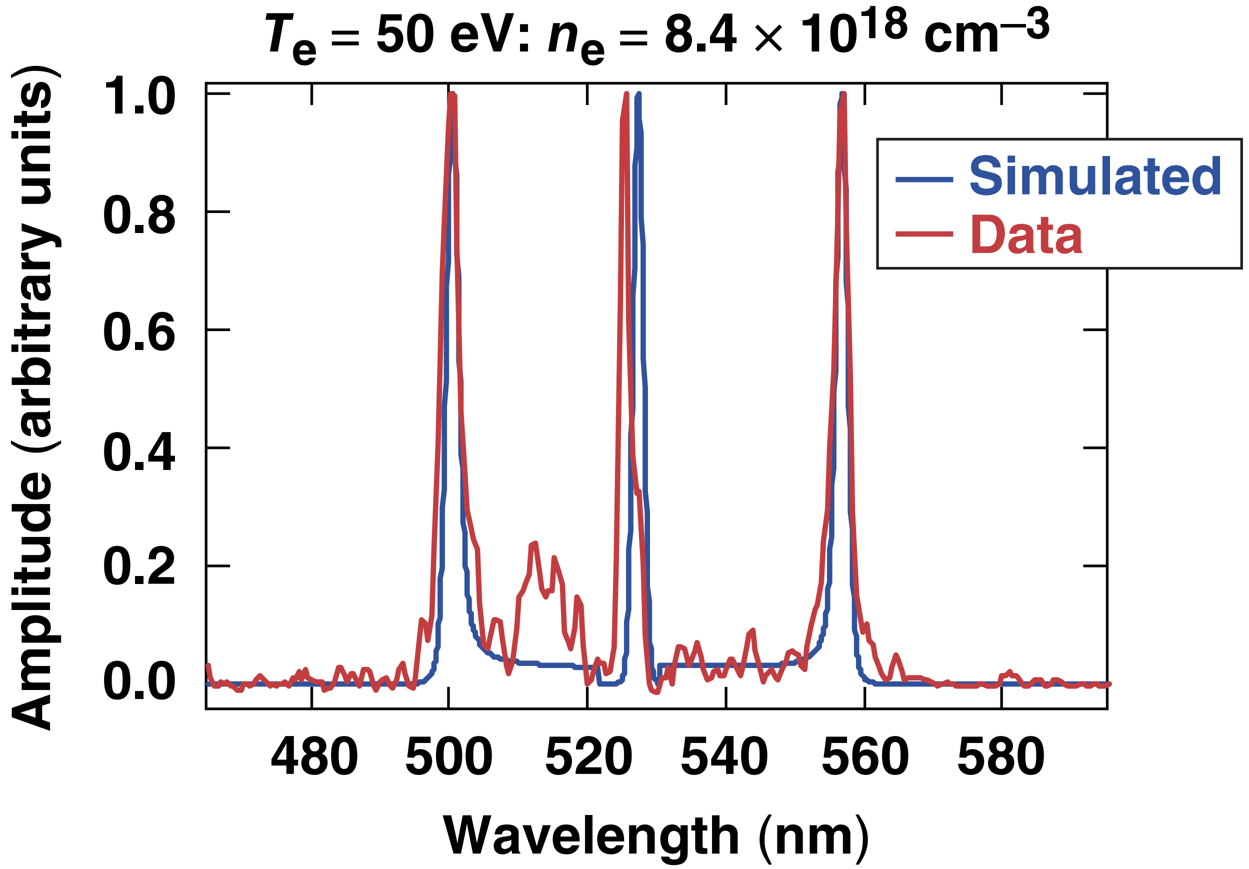
The Thomson-scattering data were fit late in time to find both the electron temperature and density





Keeping the electron density constant, the Thomson spectra were fit for all earlier times by changing the plasma temperature.

*EPW: electron plasma wave
**IAW: ion-acoustic wave

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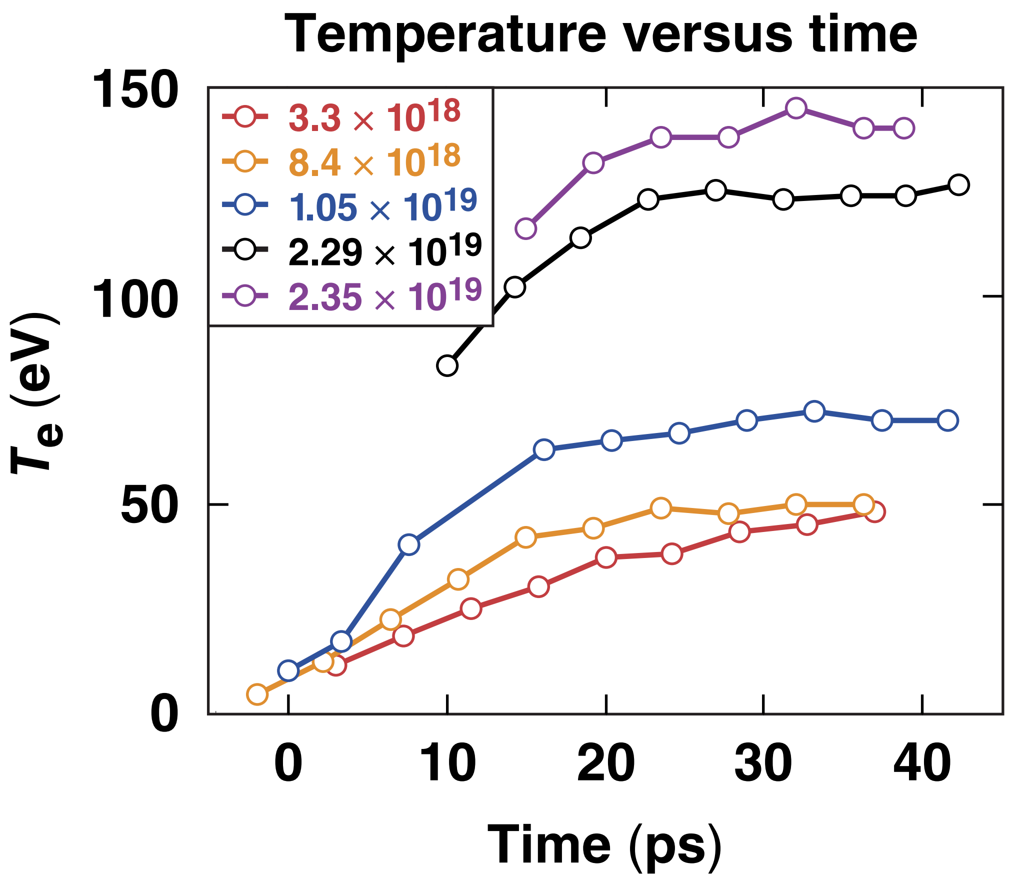
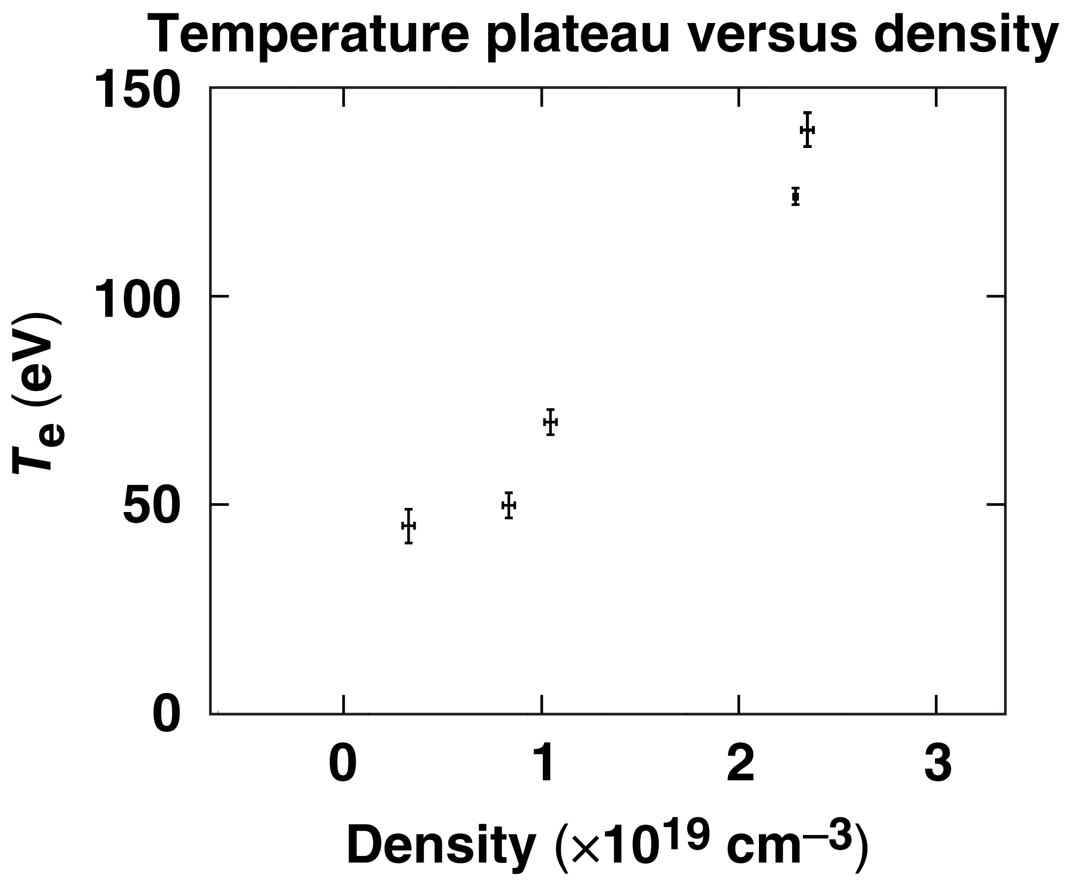
The heating rates and temperature plateaus were measured as a function of density for a 2×10^{14} W/cm^2 pump laser





As opposed to a free parameter, the temperature in a Raman amplifier is determined by the plasma density for a fixed pump intensity.

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