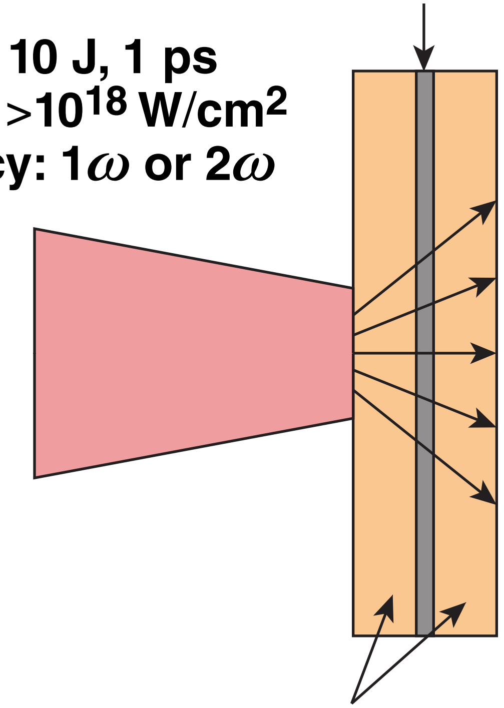
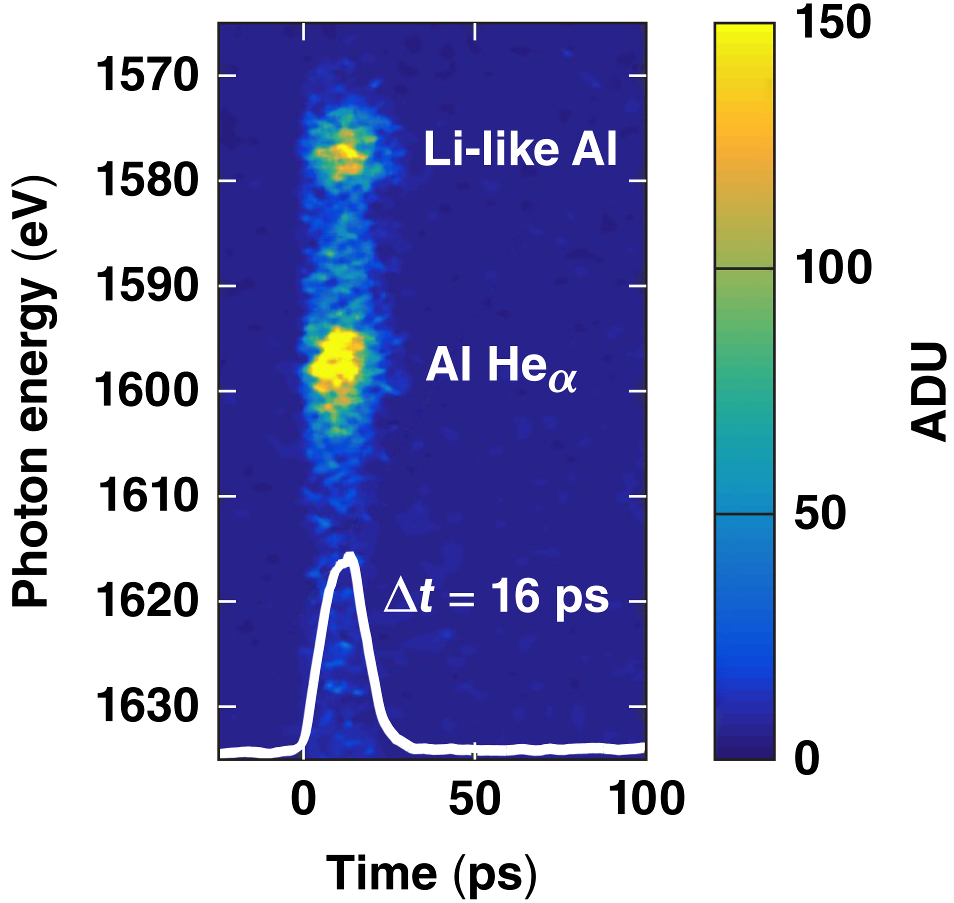
X-Ray Spectroscopy of Rapidly Heated Buried-Aluminum Layers





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Summary

Heating of a buried aluminum tracer layer was measured with ultrafast x-ray spectroscopy

- High-density and high-temperature plasma properties are important for understanding the radiative properties of stellar interiors and off-Hugoniot equations of state (EOS)
- High-intensity, short-pulse laser interactions have been used to produce hot plasmas at near-solid density
- The plasma conditions are inferred by fitting synthetic x-ray spectra from a collisional-radiative atomic physics model to the measured data

A buried aluminum layer was heated to above 300 eV at 1.8 g/cm^3 with a 10-J, 1-ps pulse.

E24573

Collaborators

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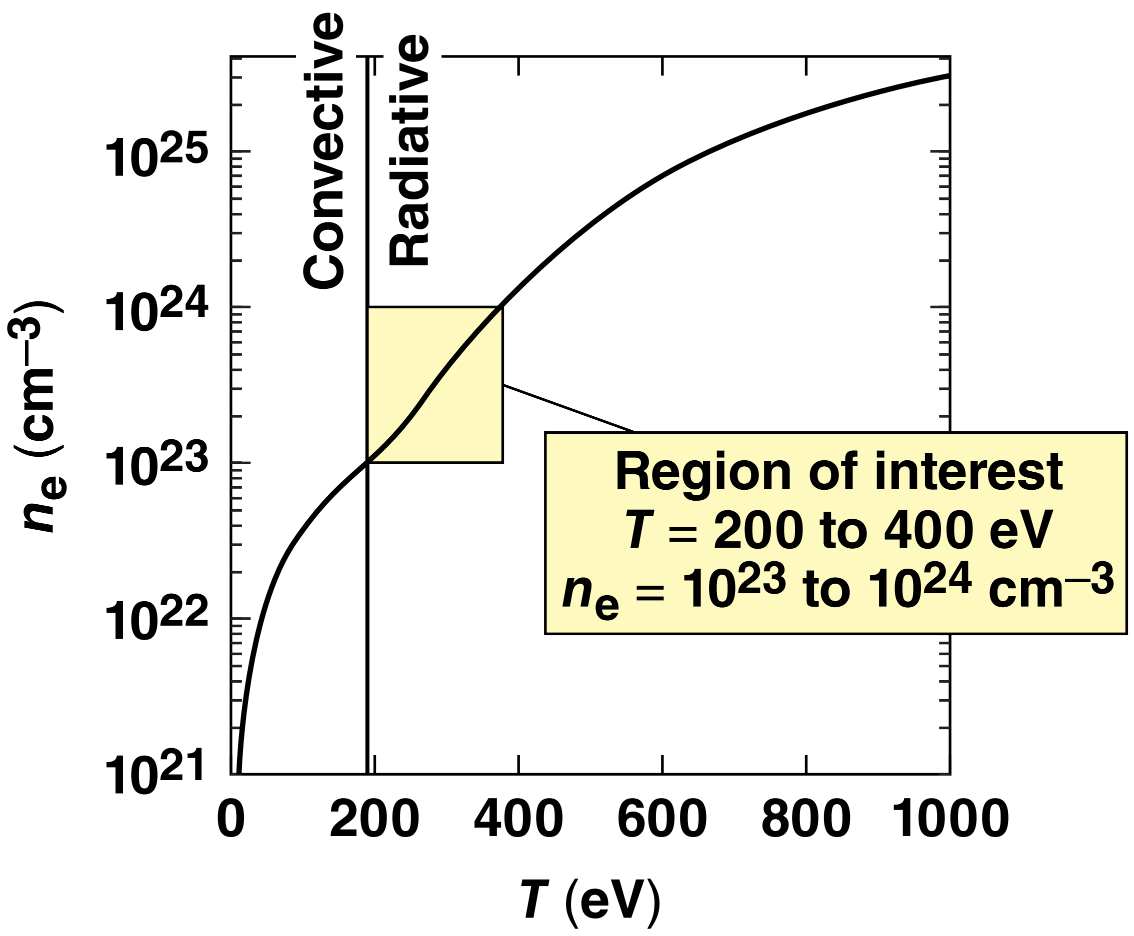
Motivation

Dense, high-temperature plasmas are required for stellar physics and radiative properties experiments

- Uncertainties exist in the radiative material properties of astrophysical plasmas
  - e.g., mean opacity of solar interior matter*
- New techniques are sought for testing
  - plasma-dependent atomic processes
  - nonequilibrium atomic kinetics
  - plasma opacity** and EOS models***

High-intensity, short-pulse lasers can heat solid matter above 500 eV.

Solar interior conditions



*J. E. Bailey *et al.*, Nature 517, 56 (2015).
**R. A. London and J. I. Castor, High Energy Density Phys. 9, 725 (2013).
***M. E. Foord, D. B. Reisman, and P. T. Springer, Rev. Sci. Instrum. 75, 2586 (2004).

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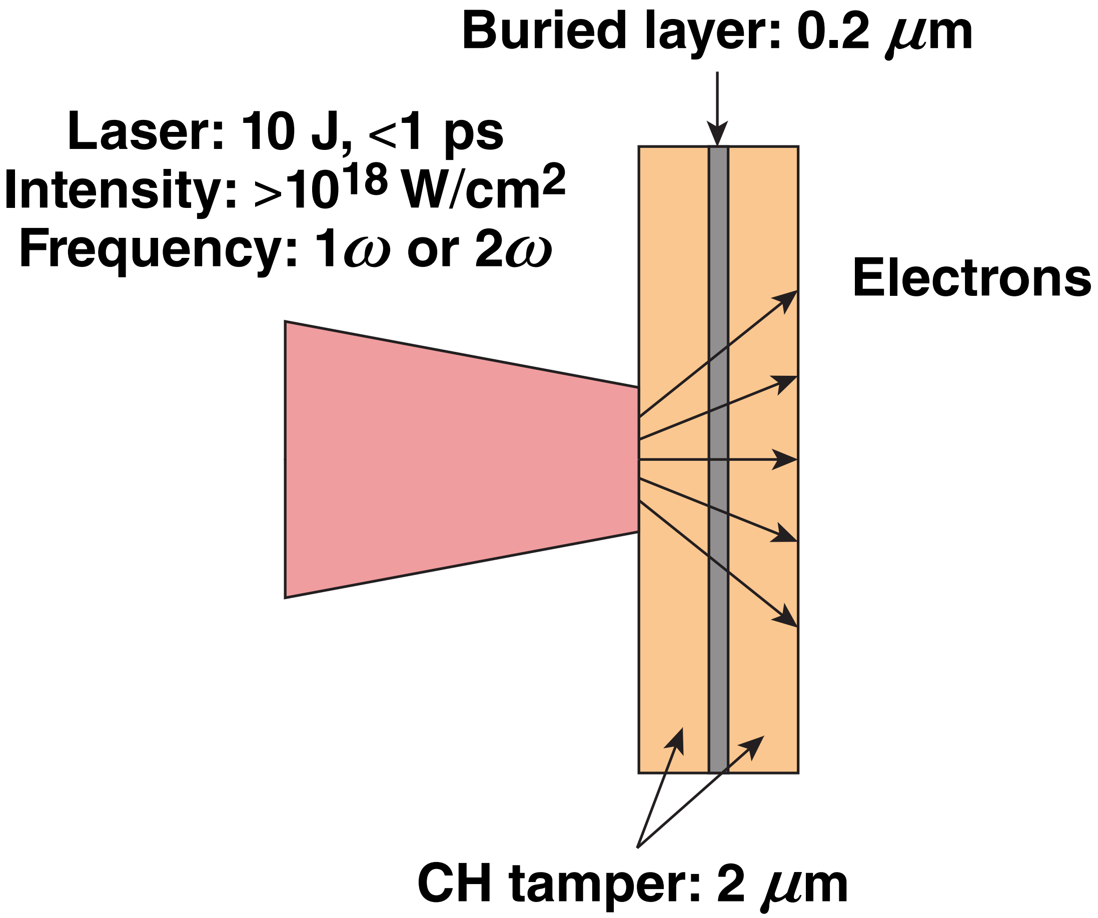
An experimental platform is being developed to study heating of near-solid density matter by laser-generated hot electrons



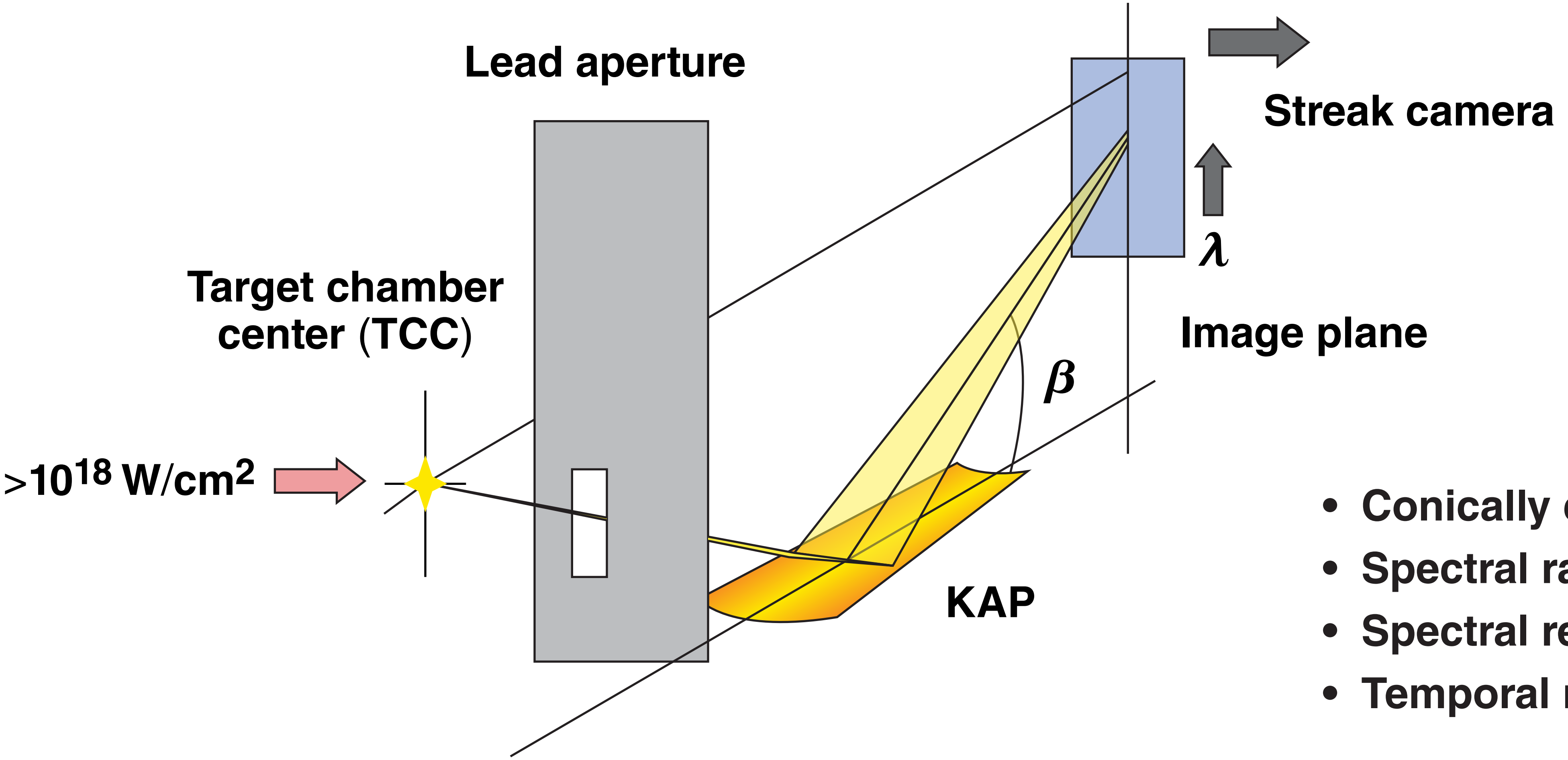
- The target is plastic and contains a buried spectroscopic tracer layer*,**
  - our initial studies have used Al
  - future experiments will use Fe
- The buried layer heats through collisional dissipation of a resistive return current
- The buried-layer emission is studied with an ultrafast streaked x-ray spectrometer

The data are compared to simulated spectra to infer the plasma conditions.

*C. R. D. Brown *et al.*, Phys. Rev. Lett. 106, 185003 (2011).
**D. J. Hoarty *et al.*, High Energy Density Phys. 9, 661 (2013).
***R. A. London and J. I. Castor, High Energy Density Phys. 9, 725 (2013).

E24575

A focusing, time-resolved Von Hamos spectrometer measures He_{α} emission from the buried layer



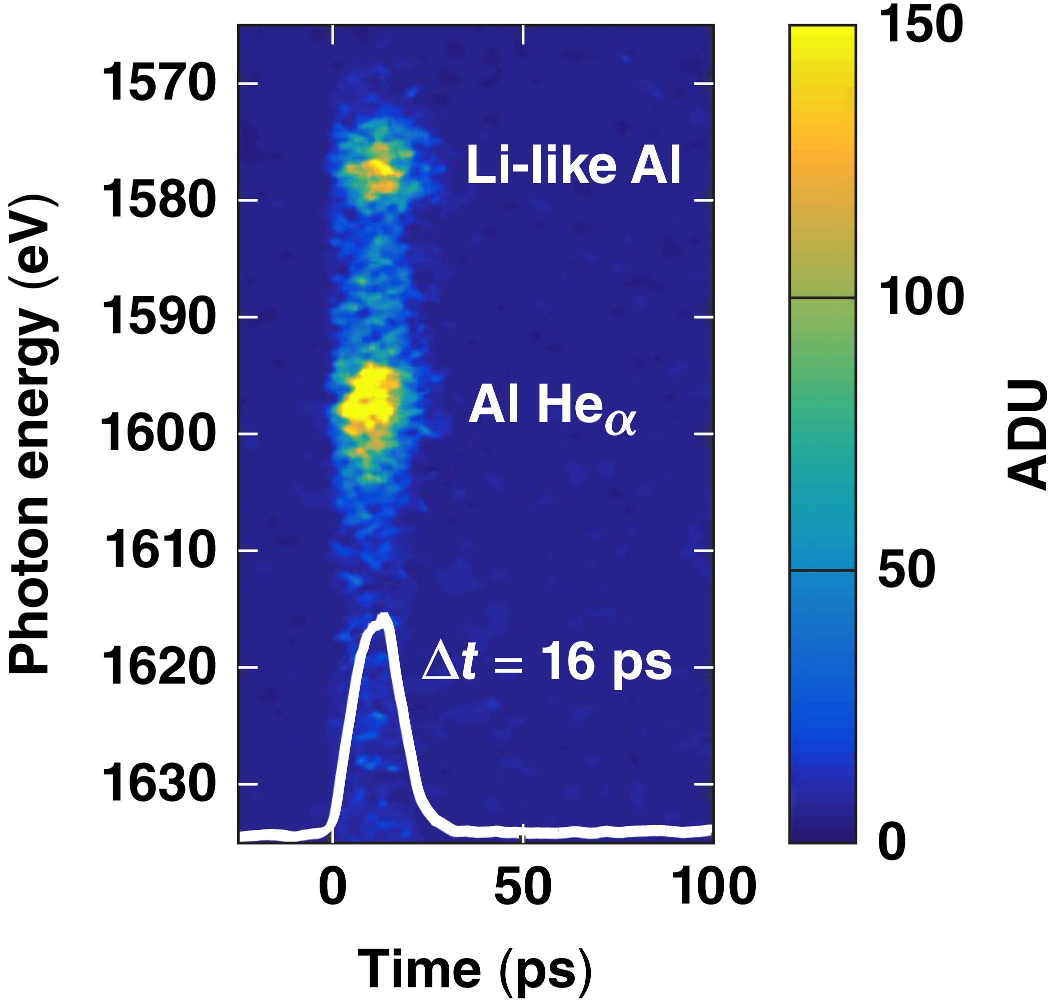
- Conically curved focusing* KAP crystal
- Spectral range ±90 eV around Al He_{α}
- Spectral resolution $E/\Delta E$ ~ 750
- Temporal resolution ~2 ps

*T. A. Hall, J. Phys. E, Sci. Instrum. 17, 110 (1984).

E24576

The first experiments used 1ω light and plastic targets containing a buried aluminum tracer layer

- Laser conditions
  - 10 J, 0.7 ps
  - intensity >10^{18} W/cm^2
- Target parameters
  - 100-μm-diam, 0.2-μm-thick Al
  - 2-μm CH tamper
- The thermal flash duration is 16 ps



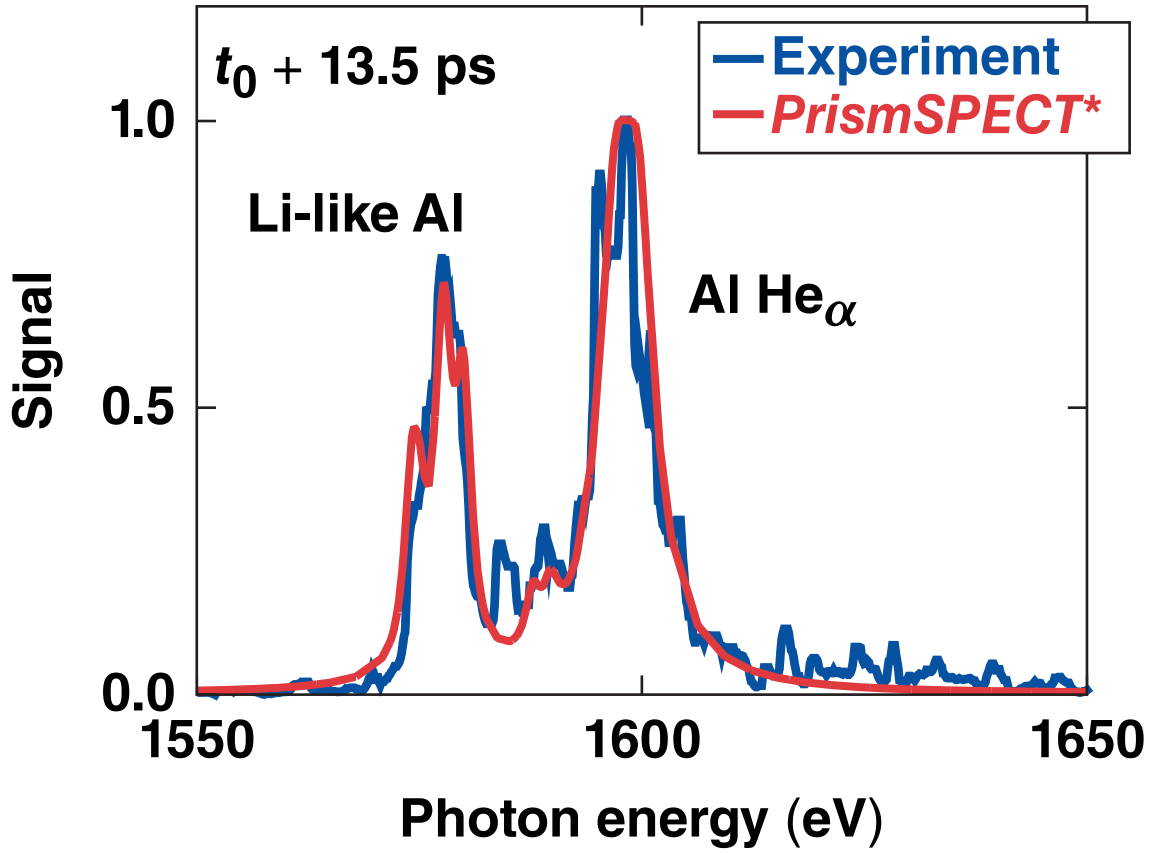
Previous studies* have shown that the hot-electron equilibration time is below 10 ps.

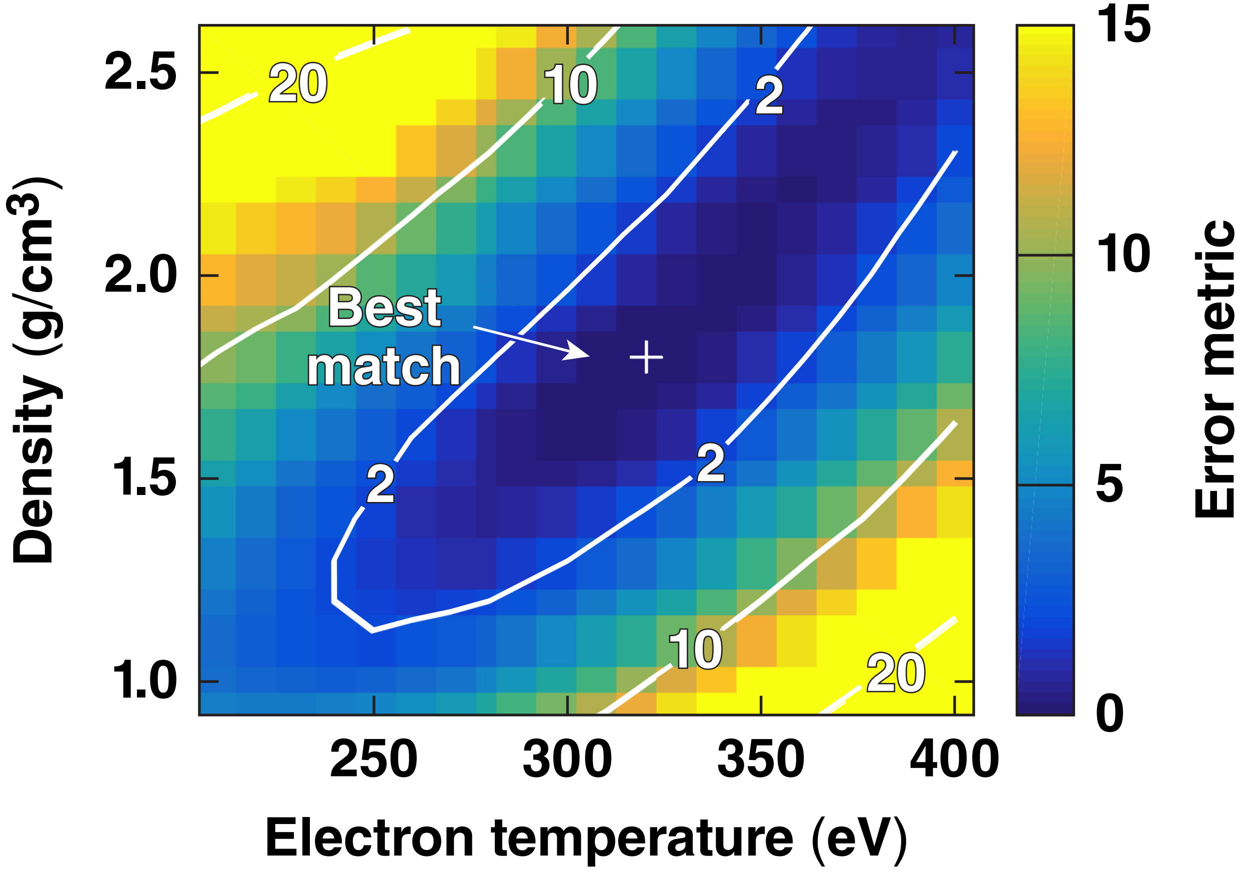
*P. M. Nilson *et al.*, Phys. Rev. Lett. 108, 085002 (2012).

E24577

The conditions in the buried layer were inferred by comparison to a local thermodynamic equilibrium (LTE) collisional-radiative model

T_e = 320 eV, ρ = 1.8 g/cm^3





Comparison to non-LTE models is underway to investigate the effects of non-equilibrium plasma conditions.

E24578

*J. J. MacFarlane *et al.*, High Energy Density Phys. 3, 181 (2007).

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