X-Ray Spectroscopy of Rapidly Heated Buried-Aluminum Layers

Buried layer: 0.2 μm
Laser: 10 J, 1 ps
Intensity: >10^{18} W/cm^2
Frequency: 1ω or 2ω

CH tamper: 2 μm
Electrons

Photon energy (eV)

Time (ps)

0 50 100

50 100 150

ADU

150

0

Li-like Al
Al He_α

Δt = 16 ps

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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/cm³ with a 10-J, 1-ps pulse.
Collaborators

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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.

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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.

**D. J. Hoarty et al., High Energy Density Phys. 9, 661 (2013).
A focusing, time-resolved Von Hamos spectrometer measures He$_\alpha$ emission from the buried layer

- Conically curved focusing* KAP crystal
- Spectral range $\pm$90 eV around Al He$_\alpha$
- Spectral resolution $E/\Delta E \sim 750$
- Temporal resolution $\sim 2$ ps

The first experiments used $1\omega$ 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-$\mu$m-diam, 0.2-$\mu$m-thick Al
  - 2-$\mu$m CH tamper

- The thermal flash duration is 16 ps

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

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

\[ T_e = 320 \text{ eV}, \rho = 1.8 \text{ g/cm}^3 \]

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

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