Material Release at High-Energy Densities

Aluminum release isentrope

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The equation-of-state (EOS) isentrope has been determined in an isochorically heated Al plasma.

• Material release was investigated using planar aluminum targets heated with a 10-ps burst of energetic electrons.

• X-ray penumbral imaging shows target decompression over a nanosecond period after the initial target-heating phase.

• The measured density profiles were used to infer the $P(\rho)$ release isentrope for the initial target conditions (few eV) and compared to SESAME predictions.

The peak densities $(1.7 \pm 0.1 \text{ g/cm}^3)$ are 3× higher than previous release-isentrope measurements.*

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*D. J. Hoarty et al., High Energy Density Phys. 8, 50 (2012).
Collaborators

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Motivation

Isochoric heating provides a unique route to warm dense matter (WDM) and high-energy-density-plasma conditions.

• WDM systems start as a solid and end as a plasma
• Found in stellar interiors, cores of large planets, and inertial confinement fusion (ICF) implosions
• Significant uncertainties exist in WDM equation of state

Measurements are required for model development.

The $P(\rho)$ release isentrope is obtained from a single density profile measurement*

- Planar solid target
- Sound speed $c_s = \frac{1}{\rho t} \int_x^{x_{\text{max}}} \rho dx$
- Pressure $P = \int_x^{x_{\text{max}}} c_s^2 \frac{\partial \rho}{\partial x} dx$
- Assumes isochoric heating and conversion of thermal energy into $PdV$ work alone

An independent measure of $c_s$ is not required.

X-ray penumbral imaging provides 1-D absorption profiles with few-micron resolution*

Aluminum foils were heated with a 10-ps burst of energetic electrons.

Experiment

The reconstruction algorithm was tested by radiographing a static aluminum target

- The penumbral image was iteratively reconstructed based on a heuristic technique
- A pyramid-style architecture was used to obtain optimal reconstruction
- The reconstructed density profile is insensitive to the initial test profile

No prior knowledge of the plasma-density profile is required.

The measured density profile shows broad agreement with 1-D LILAC predictions at a few eV.
Results

The measured density profile shows broad agreement with 1-D LILAC predictions at a few eV.

Target: 800 × 100 × 20-μm Al
Laser: 1000 J, 10 ps
Probe time: $t_0 + 1$ ns
The inferred release isentrope shows deviations from single-temperature SESAME predictions.
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