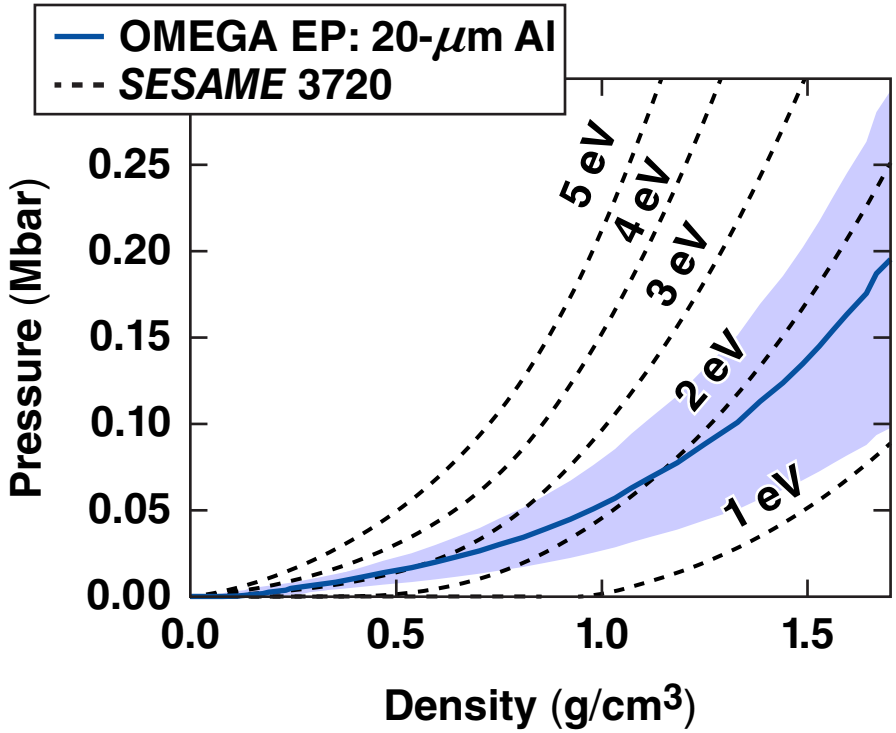
Material Release at High-Energy Densities

Aluminum release isentrope



P. M. Nilson
University of Rochester
Laboratory for Laser Energetics

55th Annual Meeting of the
American Physical Society
Division of Plasma Physics
Denver, CO
11–15 November 2013

Summary

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

UR LLE

- 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±0.1 g/cm^3) are 3× higher than previous release-isentrope measurements.*

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

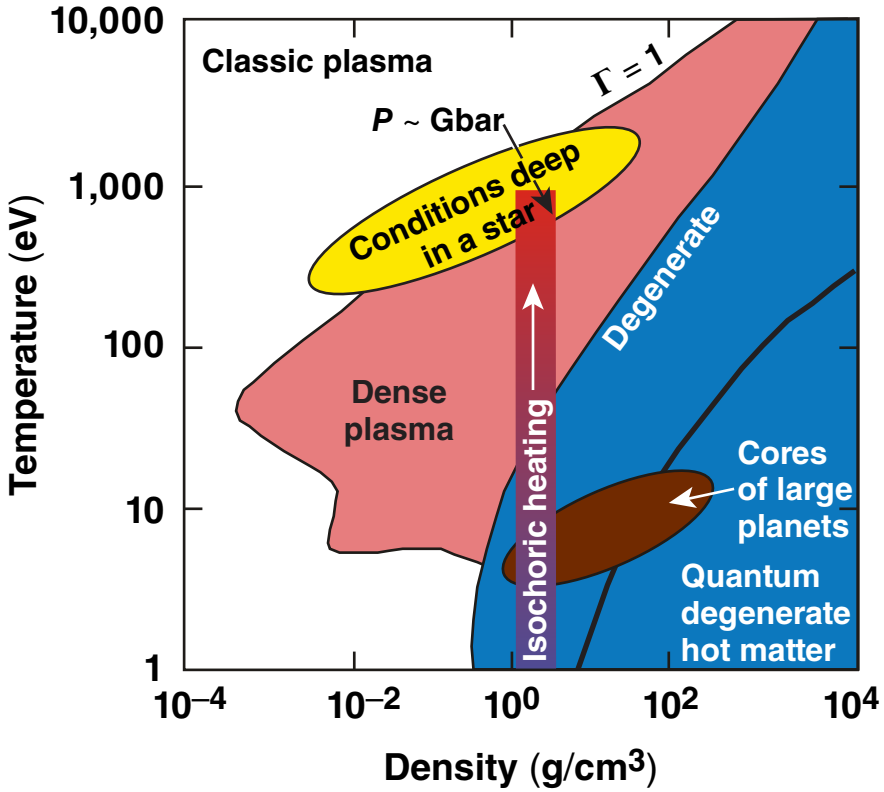
Collaborators

**C. Stillman, A. Shvydky, A. A. Solodov, R. Betti,
D. H. Froula, and D. D. Meyerhofer**

**University of Rochester
Laboratory for Laser Energetics**

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

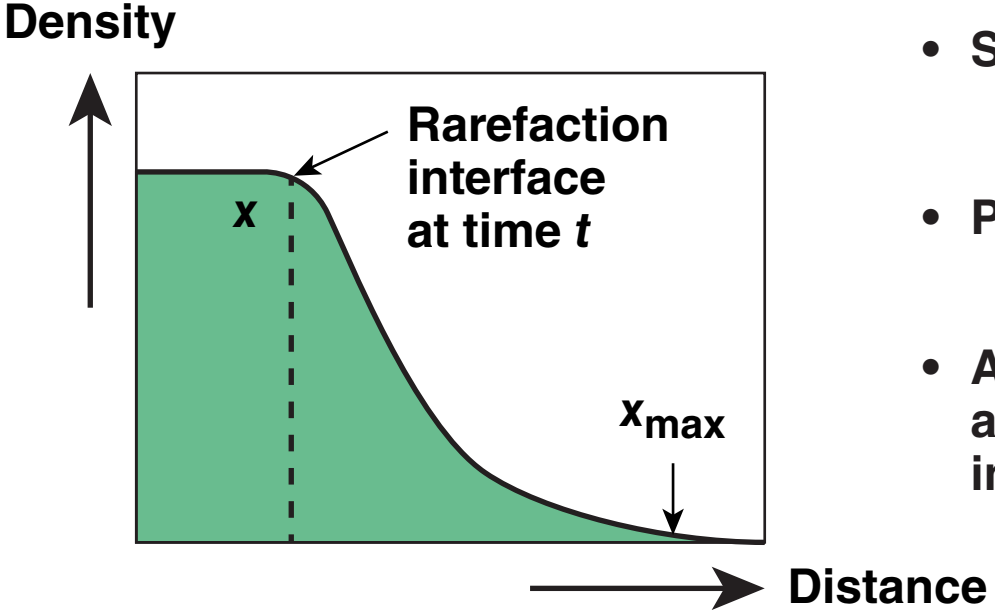
Measurements are required for model development.

A Report on the SAUUL Workshop, Washington, DC (17–19 June 2002).
R. W. Lee *et al.*, Lawrence Livermore National Laboratory, Livermore, CA, Report UCRL-TR-203844 (2004).

E21173b

Technique

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



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

An independent measure of c_s is not required.

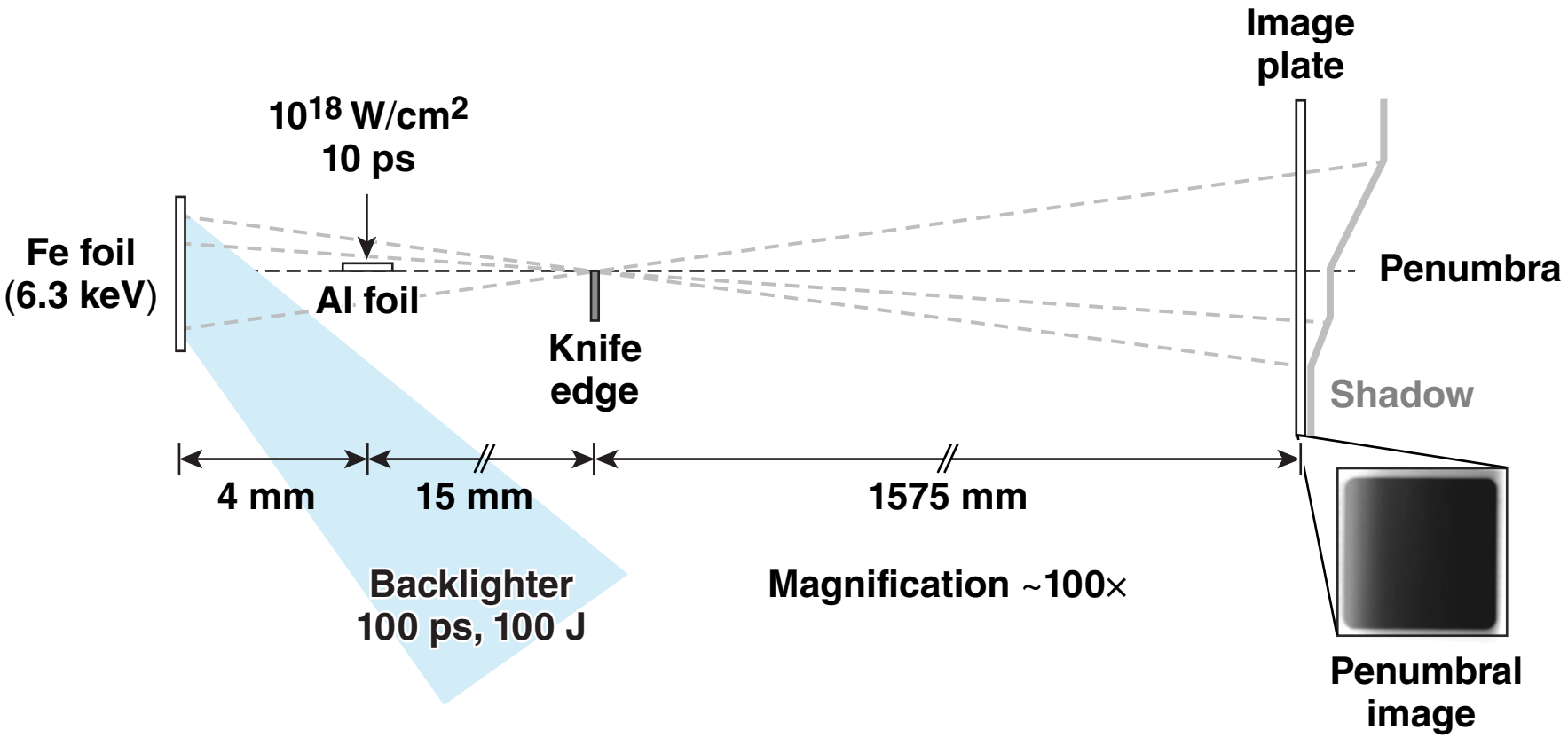
*M. E. Foord, D. B. Reisman, and P. T. Springer, Rev. Sci. Instrum. 75, 2586 (2004).

Experiment

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

UR LLE

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



*S. Fujioka *et al.*, Rev. Sci. Instrum. 73, 2588 (2002).

E22526

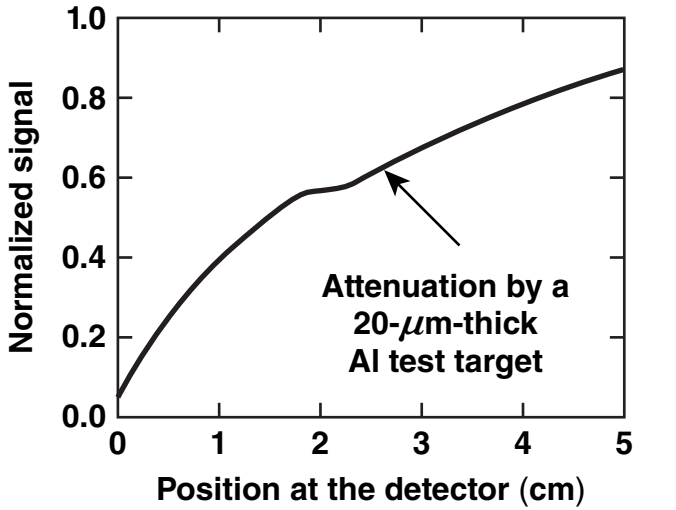
Results

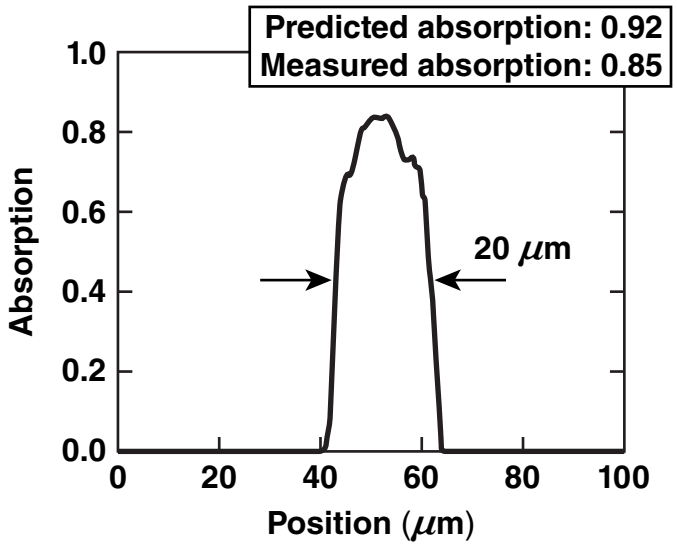
The reconstruction algorithm was tested by radiographing a static aluminum target

UR LLE

- 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.



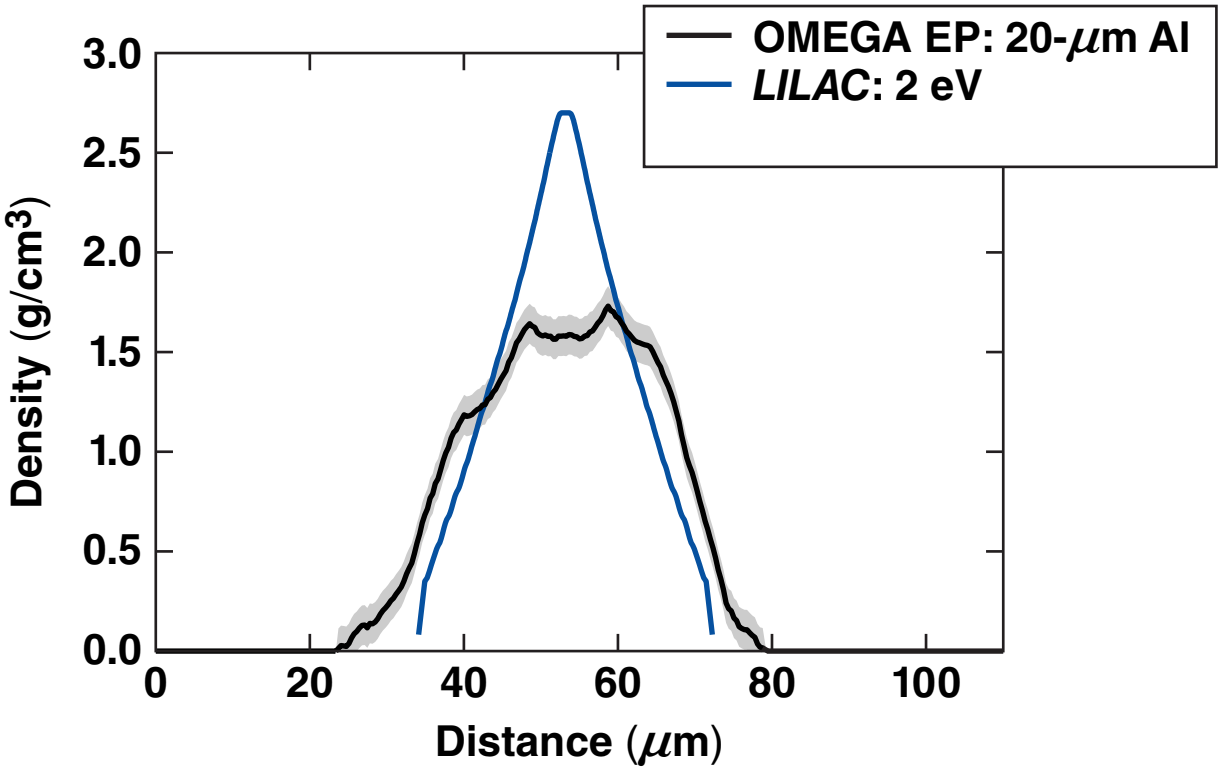


*S. Nozaki *et al.*, Rev. Sci. Instrum. 73, 3198 (2002).

E22527

Results

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

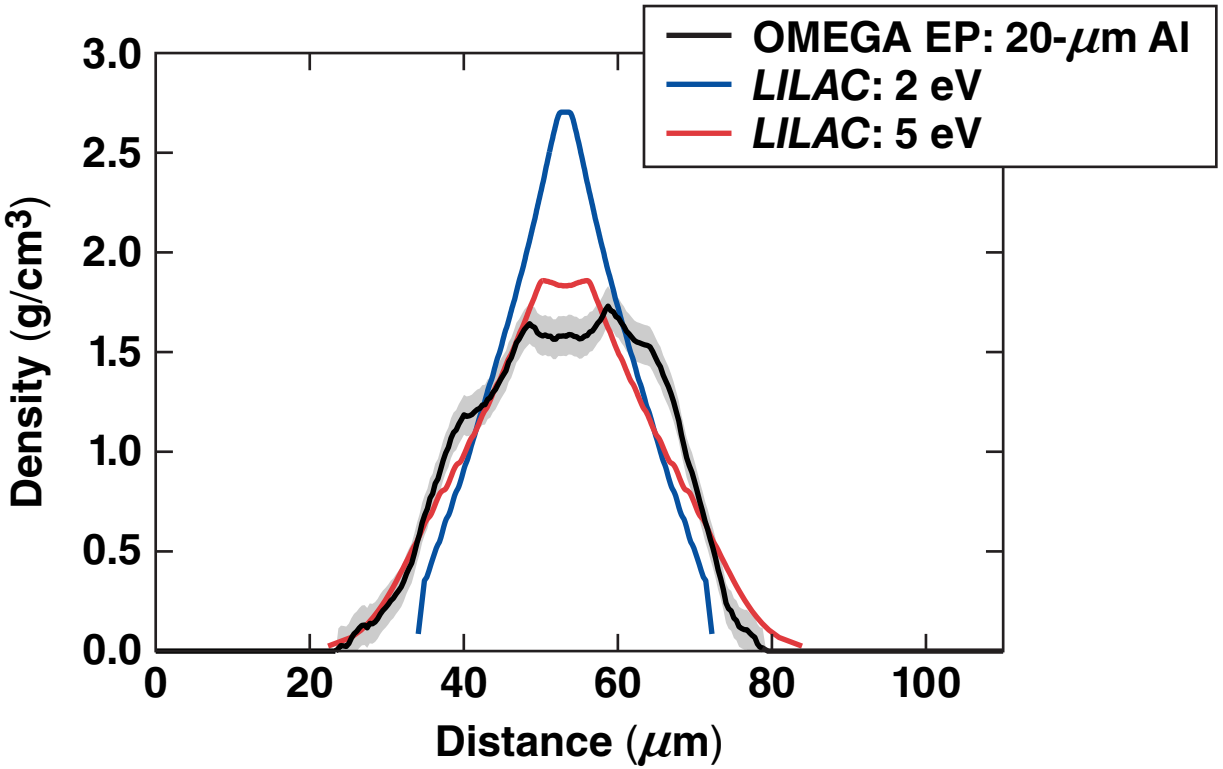


Target: 800 × 100 × 20-μm Al
Laser: 1000 J, 10 ps
Probe time: t_0 + 1 ns

E22528

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

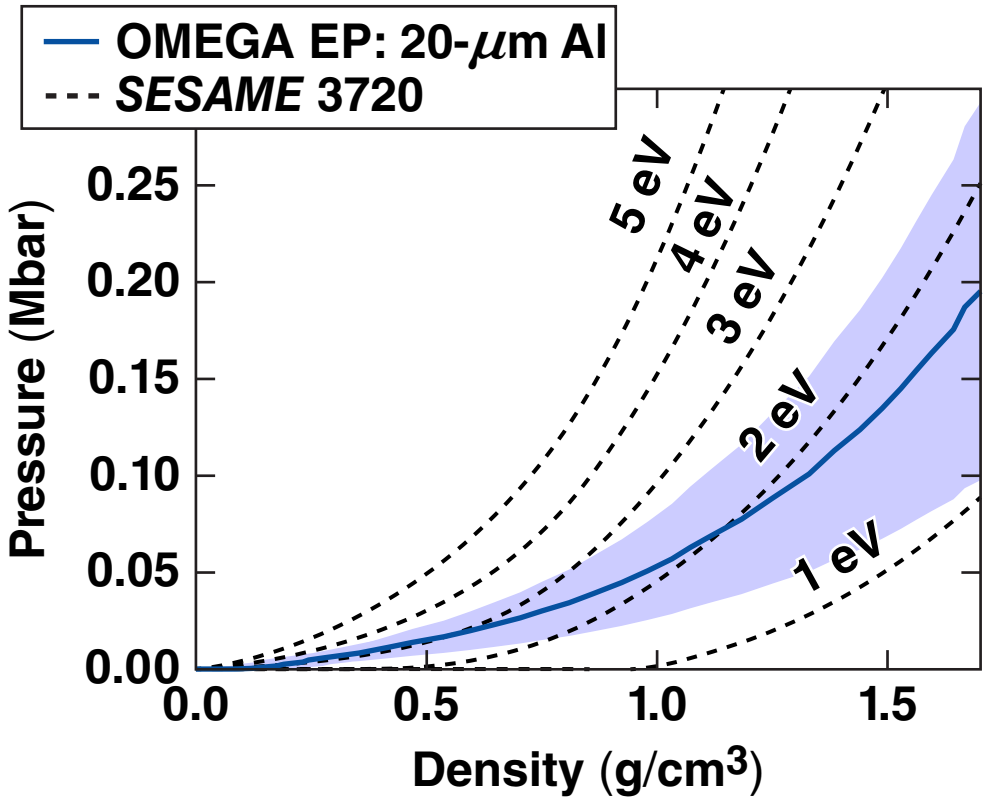
E22640

Results

The inferred release isentrope shows deviations from single-temperature *SESAME* predictions

UR LLE

Aluminum release isentrope.



E22529

Summary/Conclusions

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

UR LLE

- 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±0.1 g/cm^3) are 3× higher than previous release-isentrope measurements.*

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

E22524