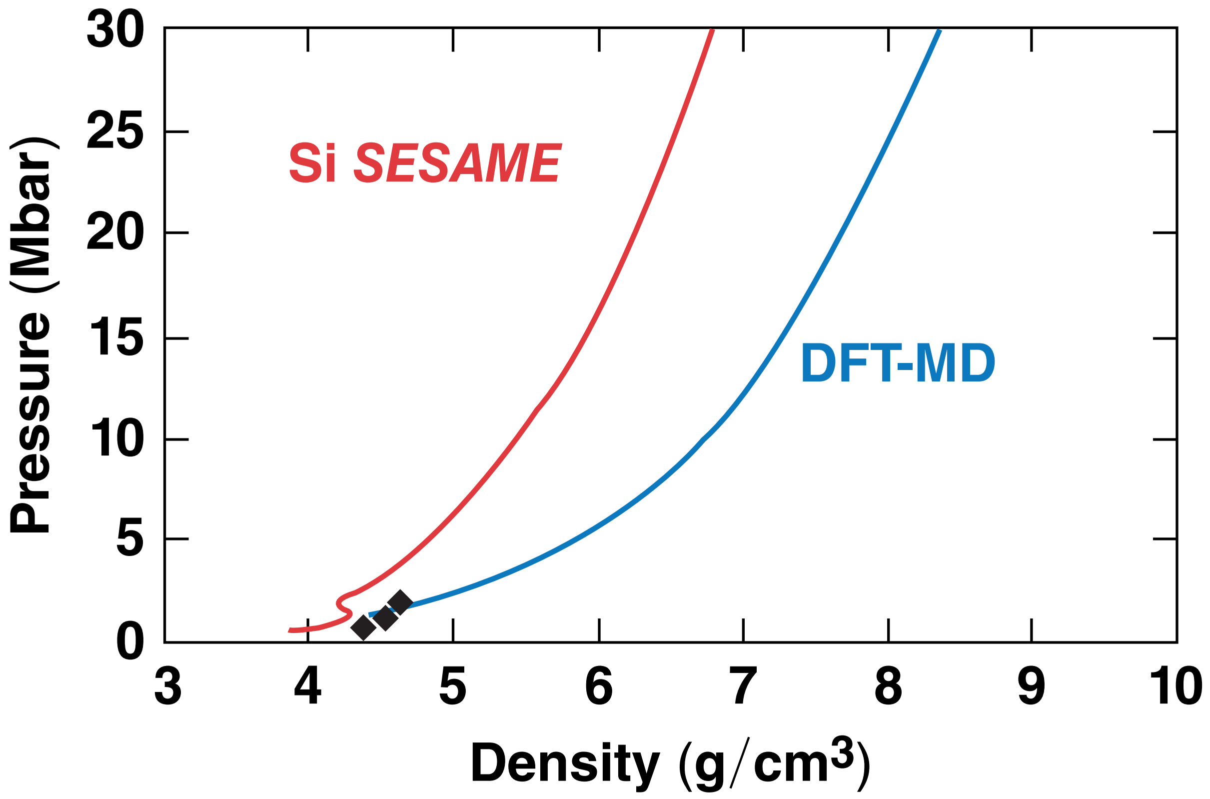
Hugoniot Measurements of Silicon



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58th Annual Meeting of the
American Physical Society
Division of Plasma Physics
San Jose, CA
31 October–4 November 2016

Summary

Laser-driven shocks were used to measure the silicon Hugoniot

- Silicon is of interest in high-energy-density (HED) physics, inertial confinement fusion (ICF) targets, geophysics, planetary science, and astrophysics
- Recent first principles calculations predict "softer" behavior than older, widely used models*
- Nonsteady waves corrections were used to reduce error in shock-velocity measurements for opaque Silicon**
- Preliminary results indicate that neither model adequately describes the high-pressure behavior of silicon

*S. X. Hu *et al*., Phys. Rev. B 94, 094109 (2016); M. C. Gregor, TI2.00003, this conference (invited).
**D. E. Fratanduono *et al*., J. Appl. Phys. 116, 033517 (2014).

Collaborators

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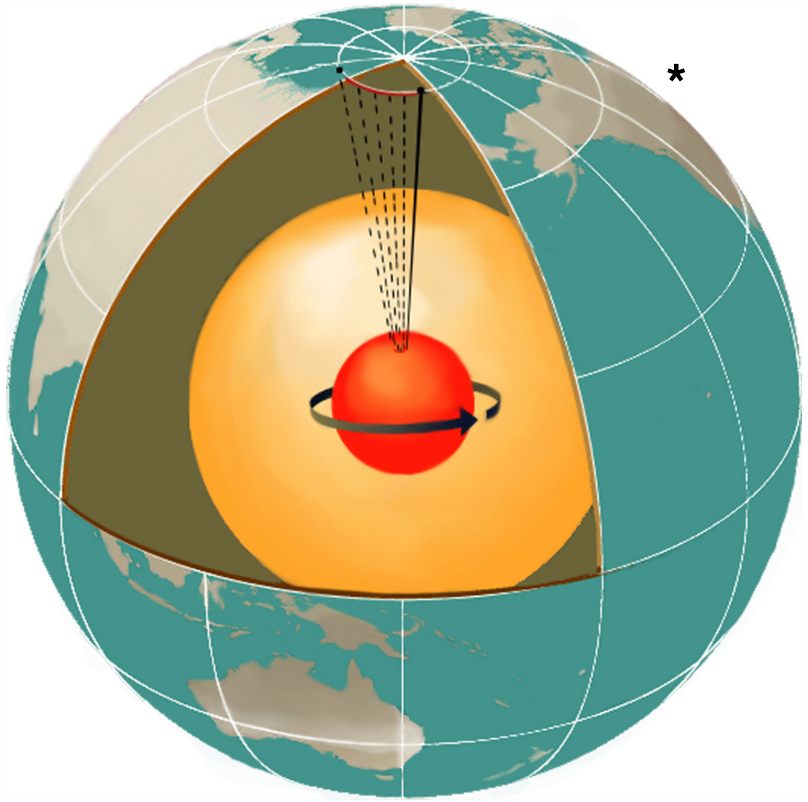
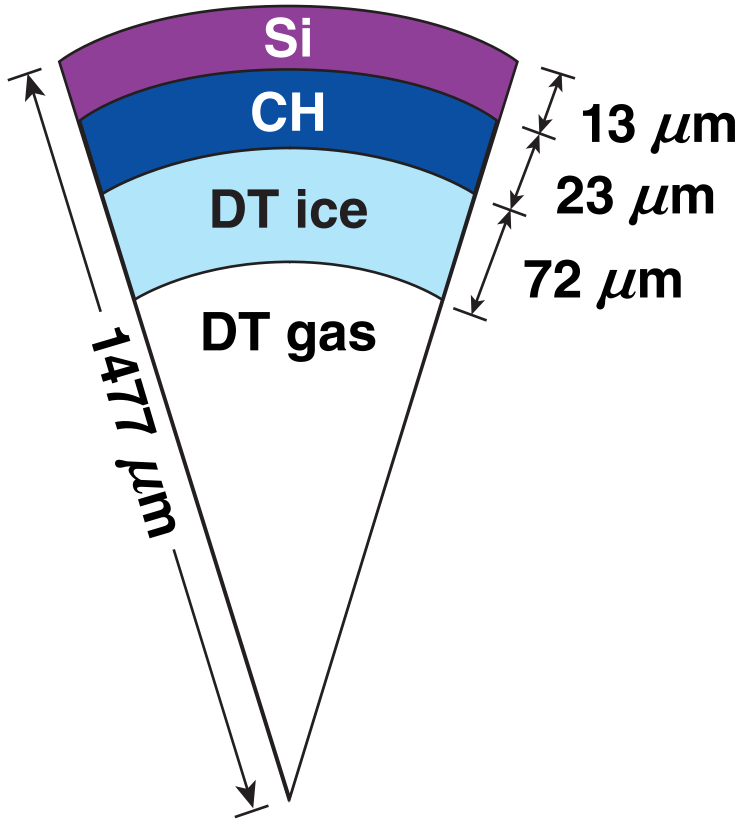
Motivation

Silicon is important to HED physics, such as planetary science and inertial confinement fusion (ICF) capsules





*http://www.nasa.gov/sites/default/files/images/607068main_world-unlabeled.jpg

Modern DFT calculations are significantly different from the standard *SESAME*

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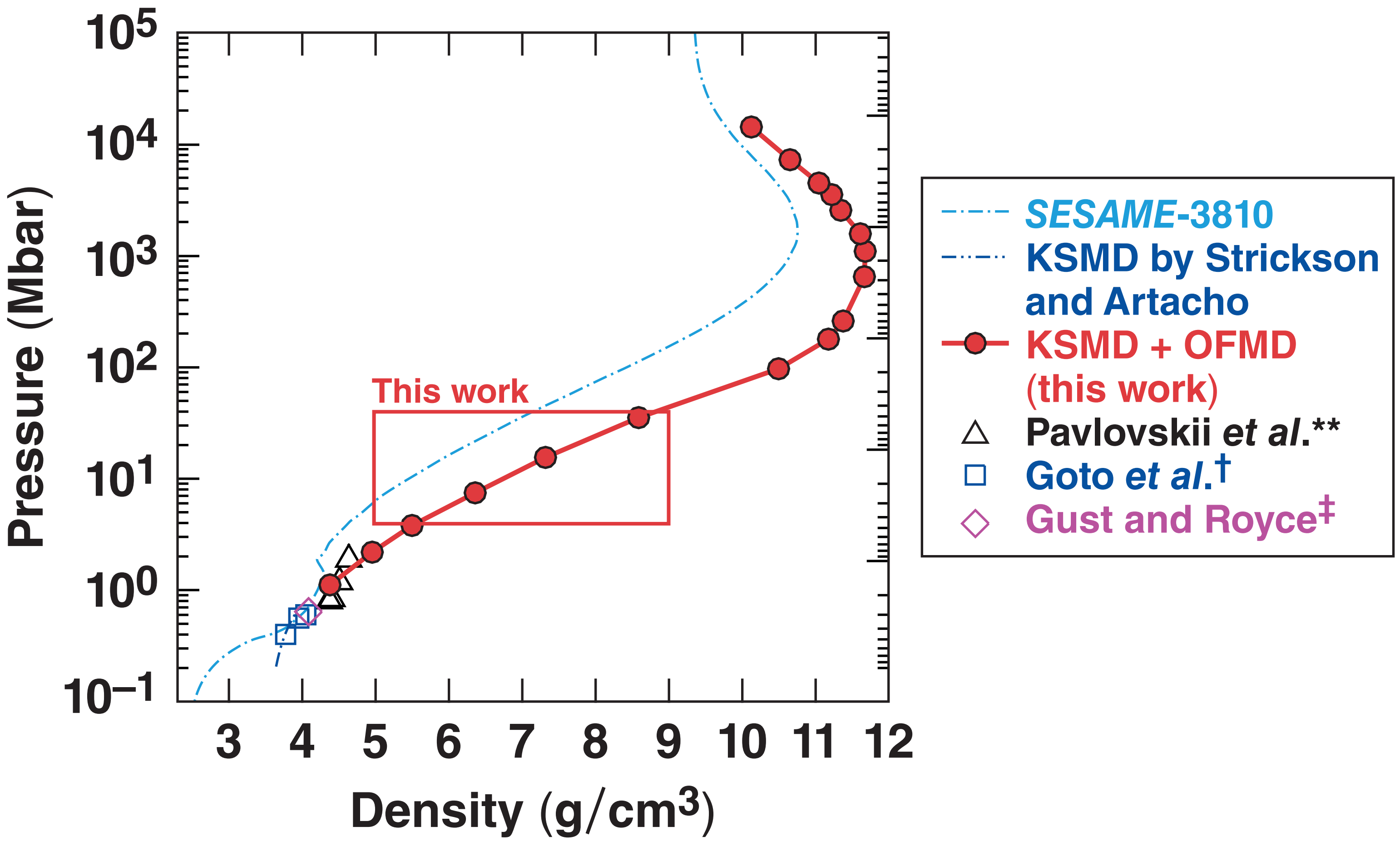
- **Below 1 Mbar, *SESAME*–EOS was constrained by Hugoniot data from 1997**
- **Above 1 Mbar, constructed so Hugoniot was "similar" to germanium**
- **The first-principles predicted shock density is ~20% higher***



DFT: density functional theory
EOS: equation of state
QEOS: "quotidian" equation of state
KSMD: Kohn–Sham molecular dynamics
PIMC: path-integral Monte Carlo
OFMD: orbital-free molecular dynamics

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*S. X. Hu *et al.*, Phys. Rev. B 94, 094109 (2016).
**M. N. Pavlovskii, Sov. Phys.-Solid State 9, 2514 (1968).
†T. Goto, T. Sato, and Y. Syono, Jpn. J. Appl. Phys. 21, L369 (1982).
‡W. H. Gust and E. B. Royce, J. Appl. Phys. 42, 1897 (1971).

The impedance-matching technique determines the pressure and particle velocity in a sample relative to a known standard

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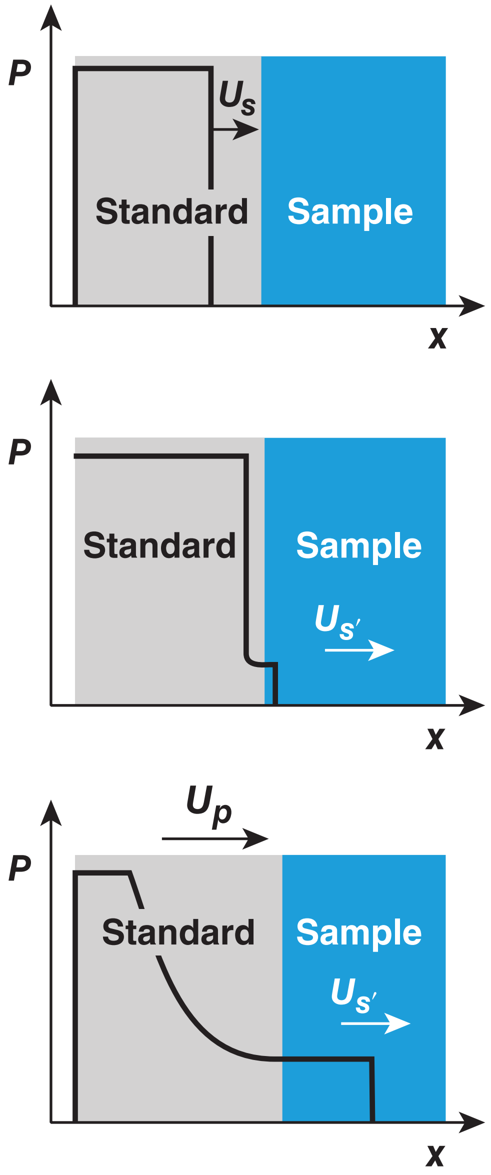
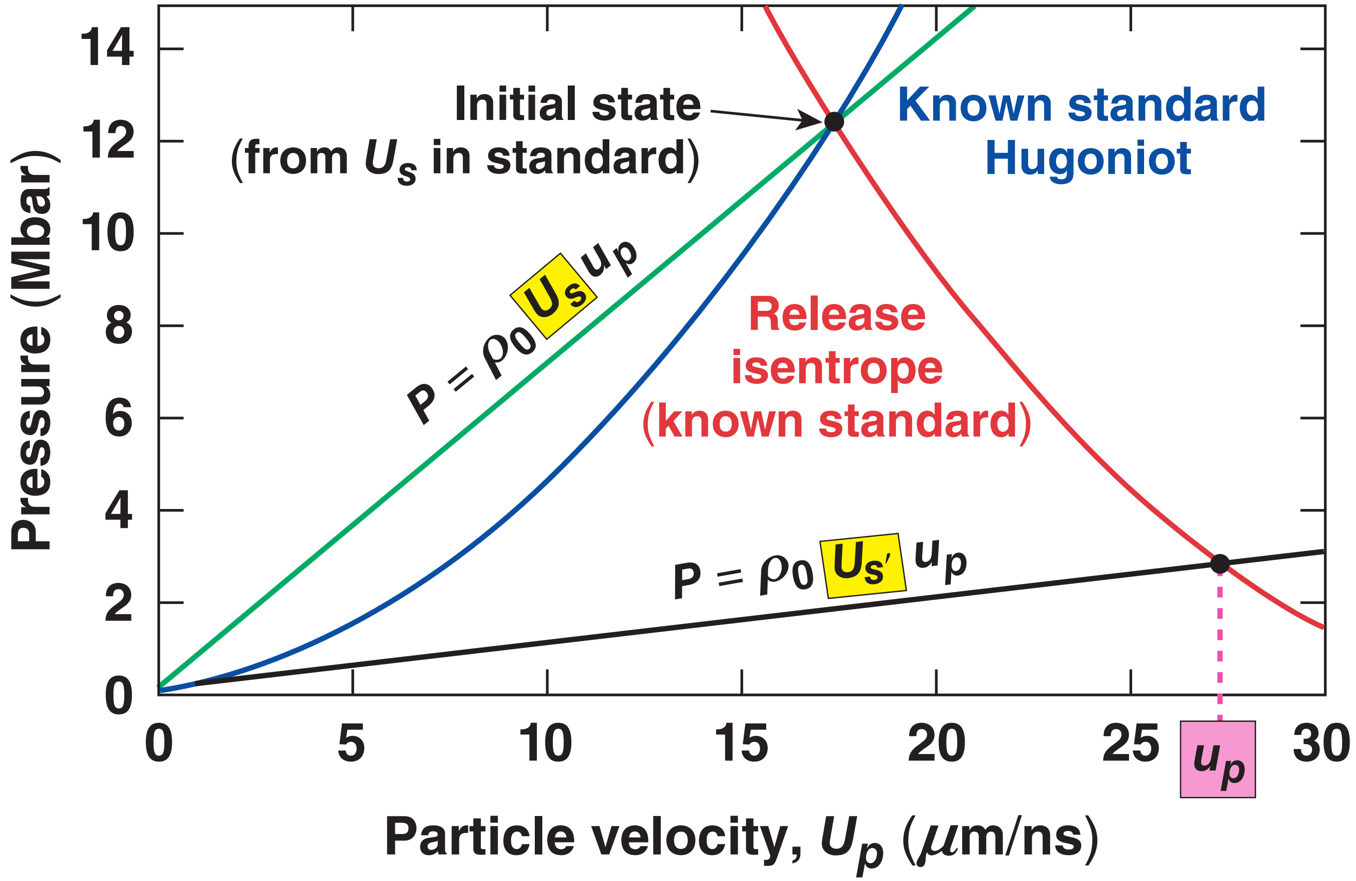
Rankine–Hugoniot relations

$$\rho_0 u_s = \rho_1 (u_s - u_p)$$

$$P_1 - P_0 = \rho_0 u_s u_p$$

$$\left[(\varepsilon_1 - \varepsilon_0) + (u_p^2/2)\right]\rho_0 u_s = P_1 u_p$$





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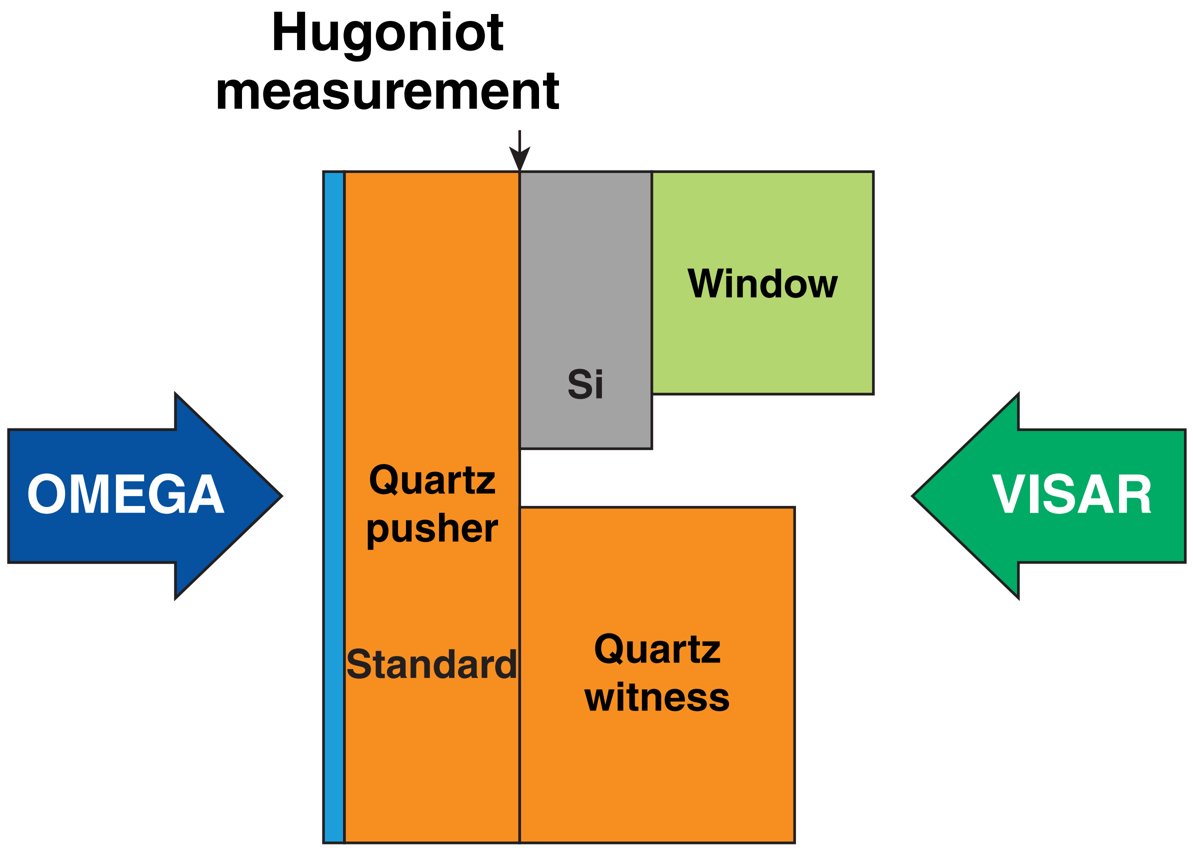
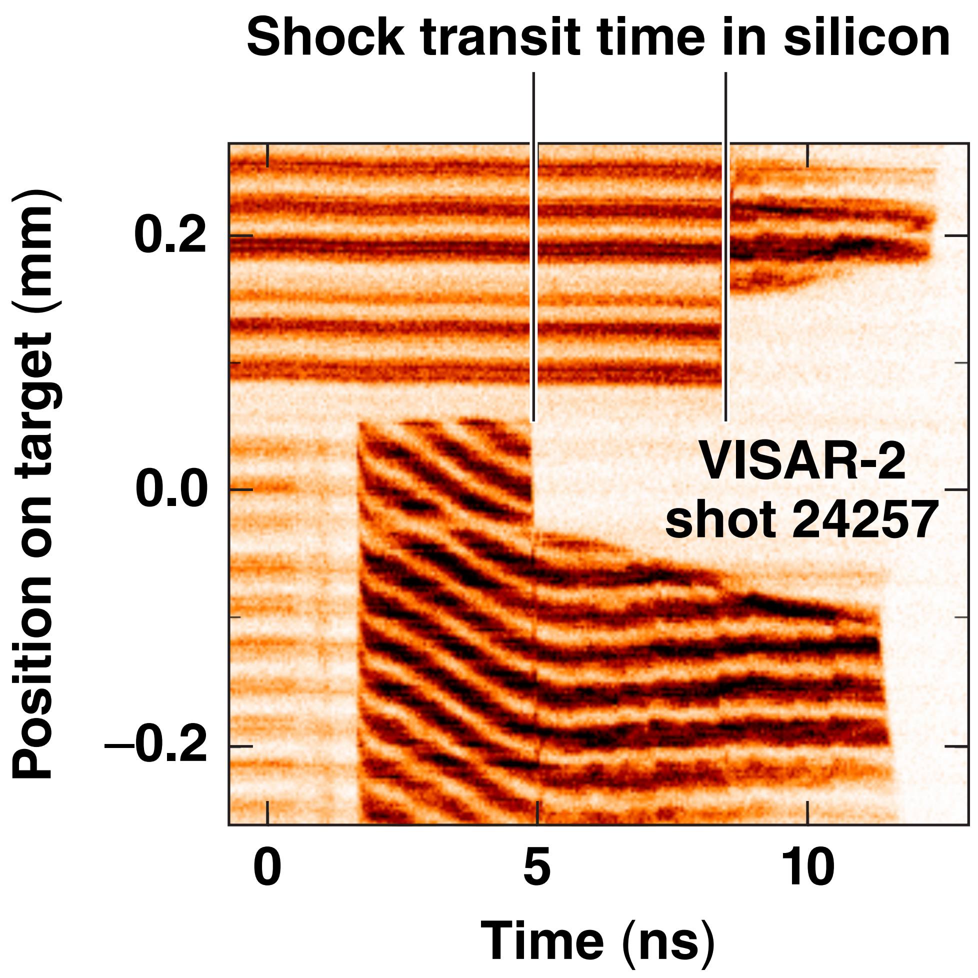
EOS measurements of opaque samples (Si) use transit times for velocity, requiring sophisticated corrections to reduce errors*

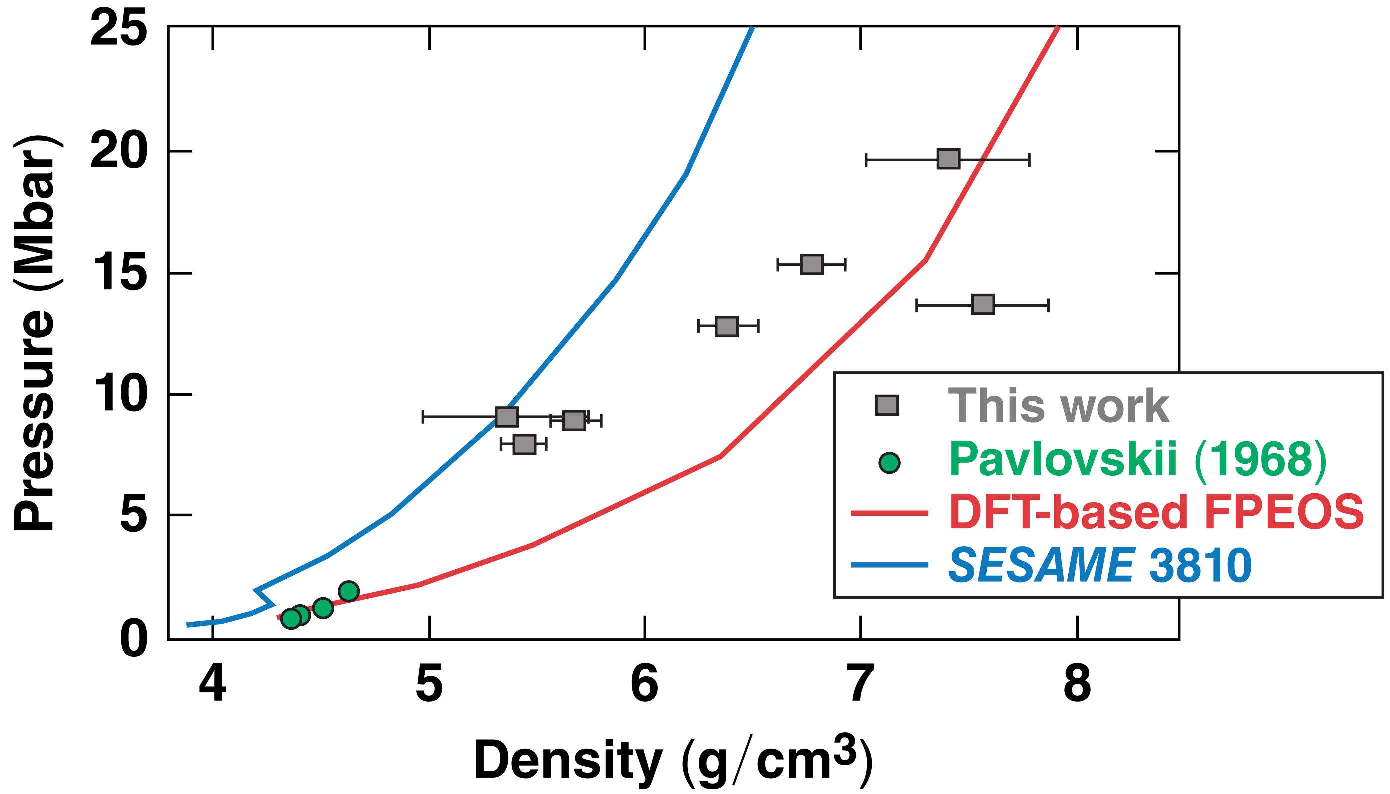




- Instantaneous shock velocities in silicon are determined using a nonsteady waves correction**

VISAR: velocity interferometer system for any reflector
*D. E. Fratanduono *et al*., J. Appl. Phys. 116, 033517 (2014).

Preliminary results indicate that neither model adequately describes silicon above 5 Mbar



- At pressures above 5 Mbar silicon, is expected to be fully in the fluid phase; phase changes are not expected

FPEOS: first-principles EOS

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