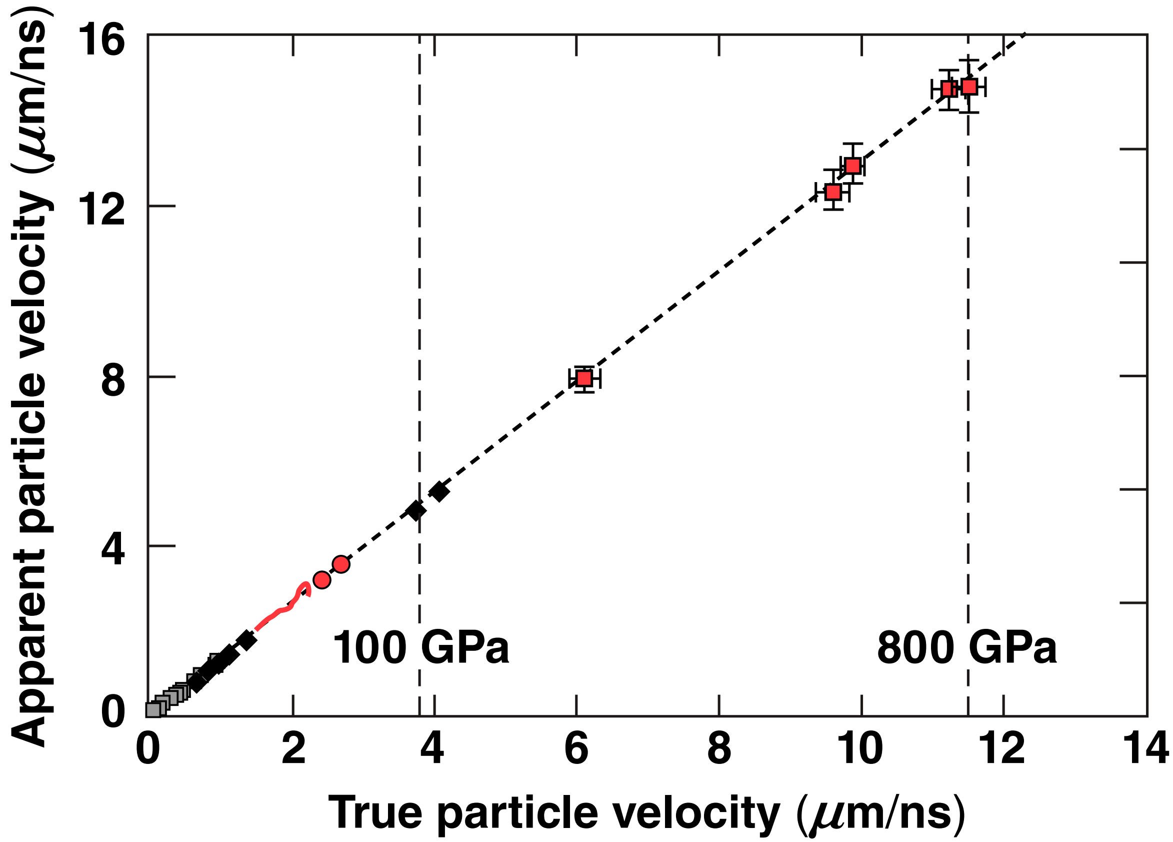
Measurements of Strain-Induced Refractive-Index Changes in LiF Using Direct-Drive Ramp Compression



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Summary

The refractive index of quasi-isentropically compressed LiF has been measured to ~800 GPa

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- The shock-compressed refractive index of LiF was previously studied to 100 GPa*
- LiF is observed to be transparent up to 800 GPa with quasi-isentropic compression
  - remains transparent for single shocks < 160 GPa
- Ramp-compressed LiF refractive index is in agreement with existing data
  - does not depend on loading technique (shock versus ramp compression)
- LiF refractive index scales linearly with density up to 800 GPa

*J. L. Wise and L. C. Chhabildas, presented at the American Physical Society Topical Conference on Shock Waves in Condensed Matter, Spokane, WA, 22 July 1985.

E18359

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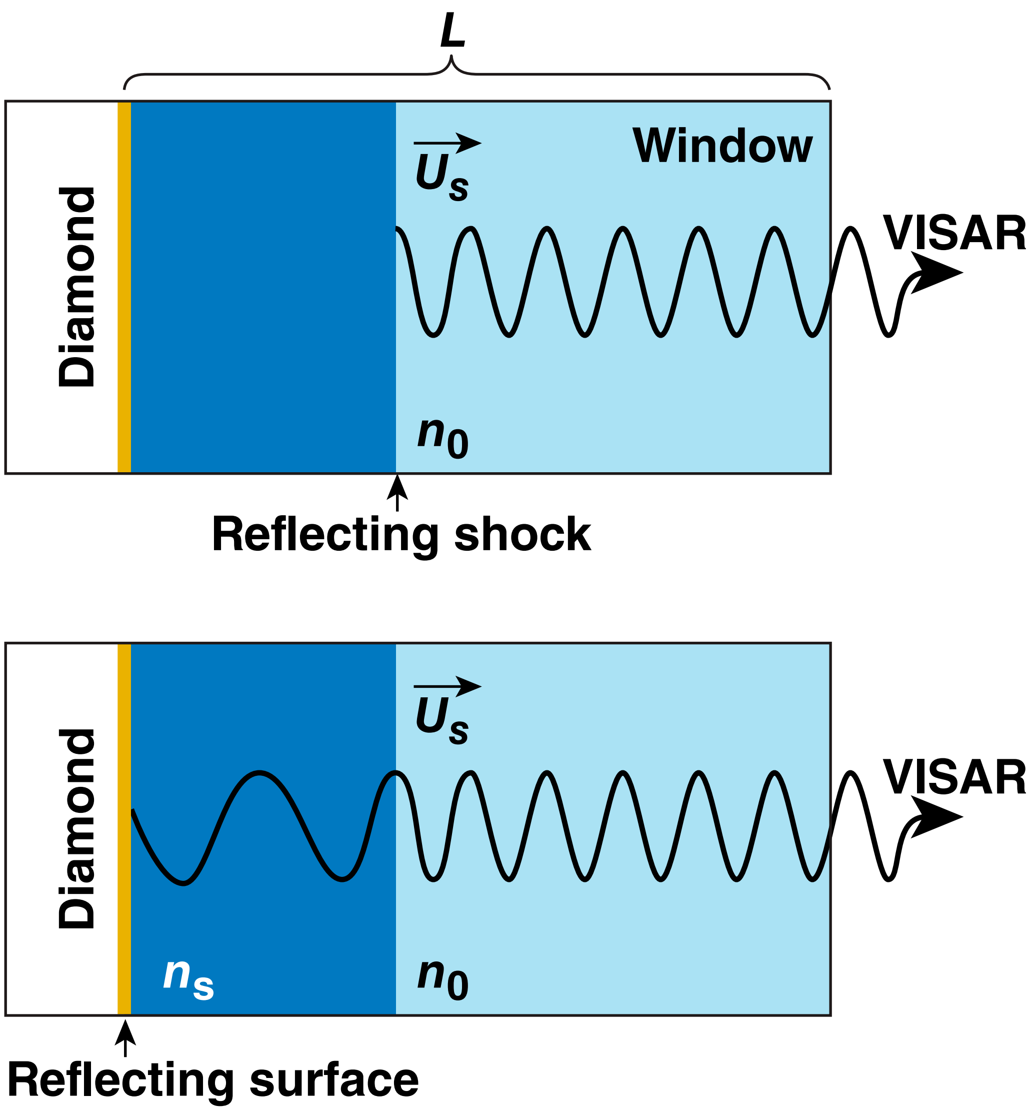
Changes in the refractive index affect VISAR measurements



- VISAR measures the rate of change of the optical path length (OPL)
- OPL depends upon n_0 and n_s

$$\mathrm{OPL} = \int_0^L n(x)\,dx$$

- Corrections must be made for shocked materials (n_s)

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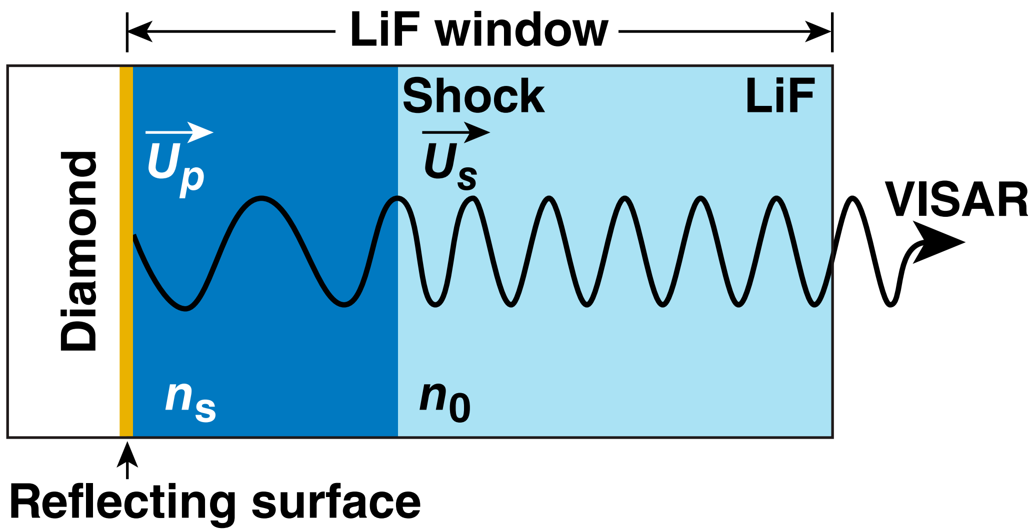
Transparency of shocks in LiF windows makes it possible for VISAR to probe the material interface



- Single shocks up to 160 GPa are transparent in LiF
  - multi-shocks up to 500 GPa are transparent
- VISAR probes through compressed material, this alters its sensitivity
- For shock compression up to 100 GPa, the refractive index scales linearly with density:* $n = a + b\rho$

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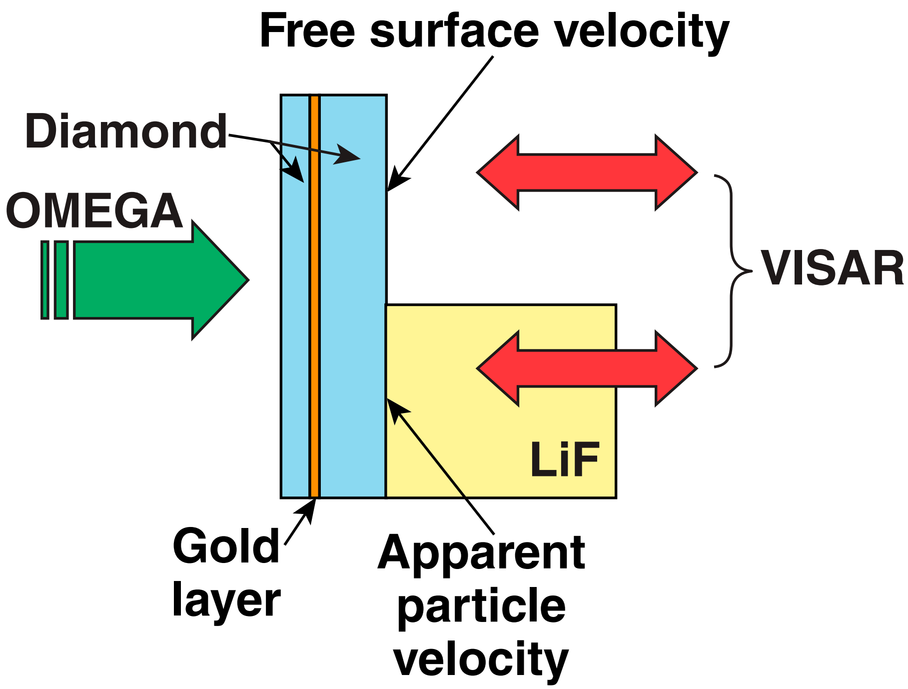
*J. L. Wise and L. C. Chhabildas, Shock Waves in Condensed Matter 1985, DEAC04-DP00789

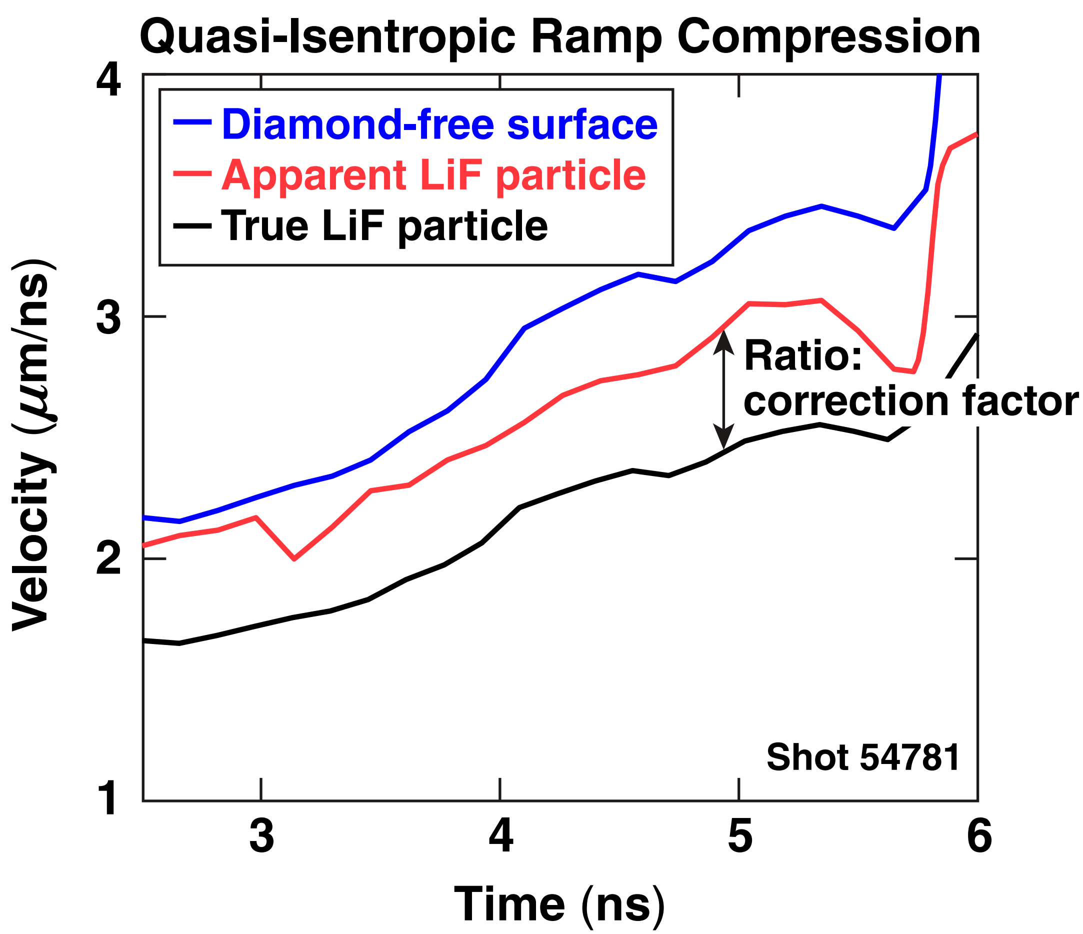
Simultaneous measurement of free-surface and apparent particle velocities provide index correction



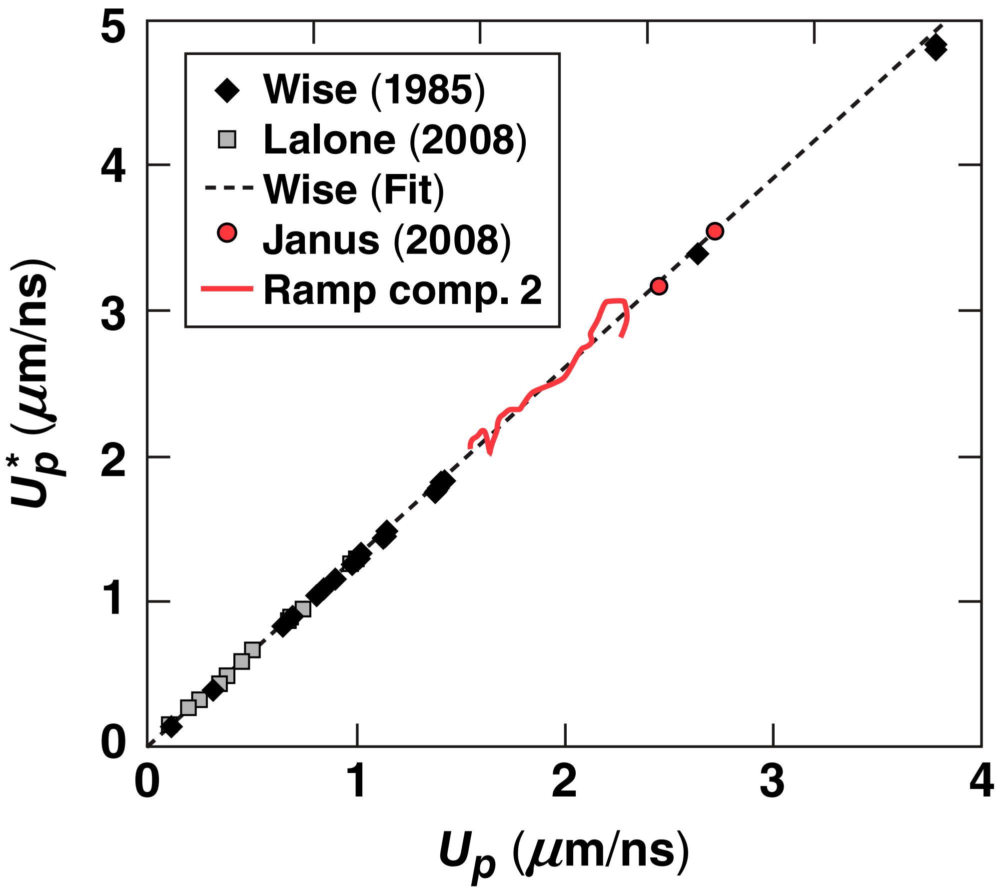
- Diamond isentrope* and LiF EOS are known
- Use impedance matching to infer true particle velocity
- Derive correction from measured versus true particle velocity

*D. K. Bradley *et al*., Phys. Rev. Lett. 102, 075503 (2009).

Apparent U_p is compared to true U_p (derived from U_{fs}) to obtain correction



Quasi-isentropic ramp compression allows for continuous measurements to be made



$$\frac{dU_p^*}{dU_p} = n - \rho\frac{dn}{d\rho}$$

- Ramp experiment exhibited higher temperatures than predicted

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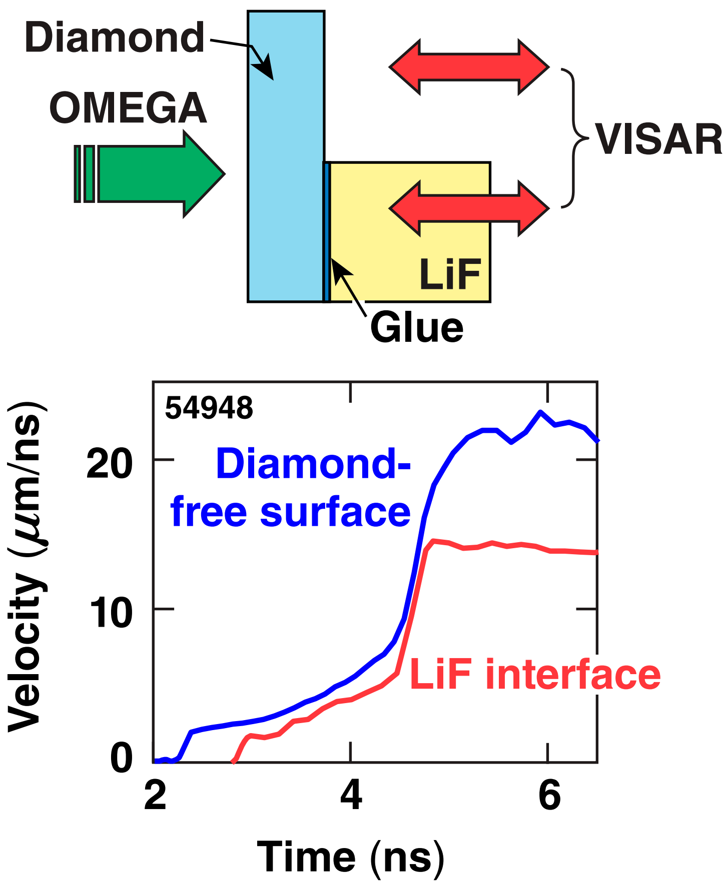
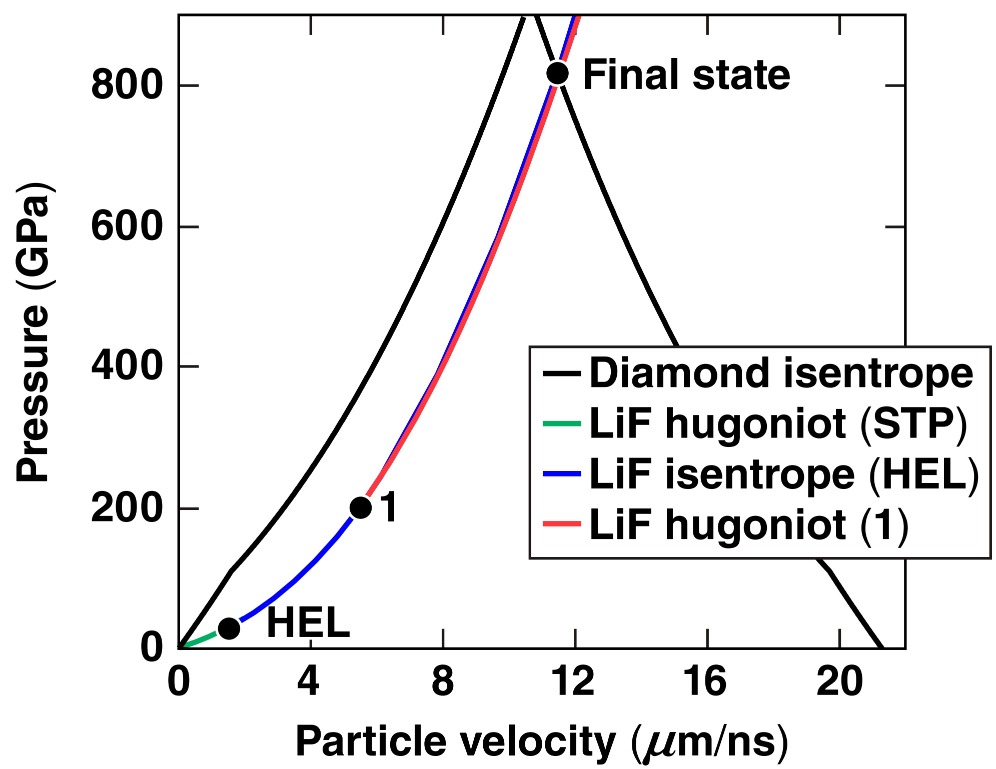
Glue layers compromised ramp measurements, but the final state can be used to obtain correction





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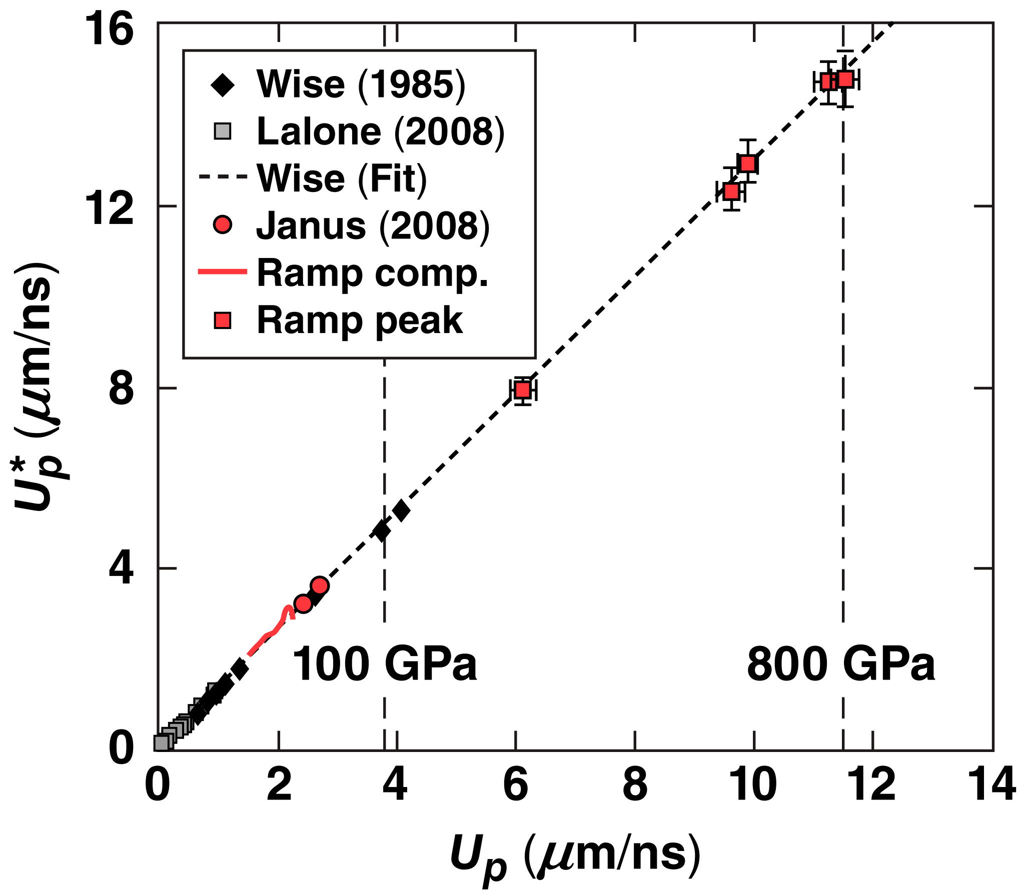
LiF refractive index depends linearly on density to 800 GPa



For compressed material:

$$\frac{dU_p^*}{dU_p} = n_s - \rho \frac{dn_s}{d\rho}$$

This case $\frac{dU_p^*}{dU_p}$ = constant

$$n_s = \text{constant} + n_0\,\rho$$

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Summary/Conclusions

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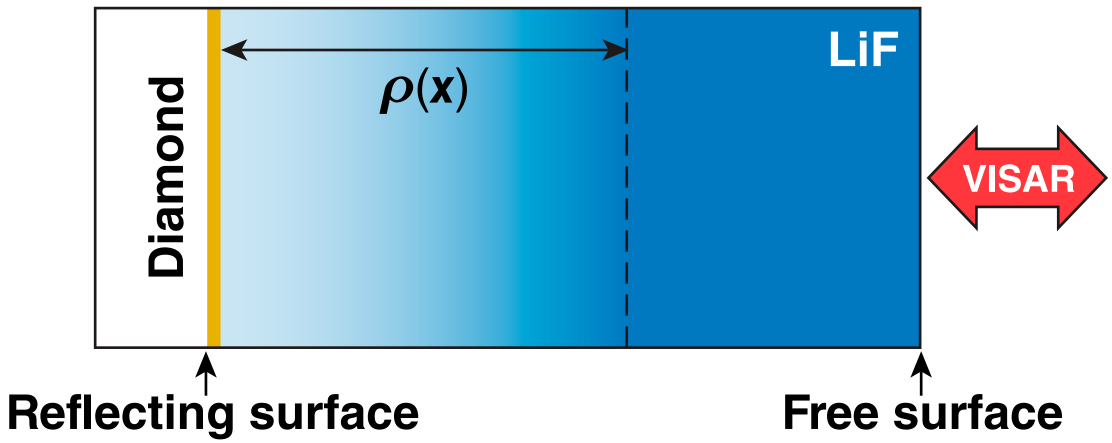
The optical path length of linear window materials does not affect the particle velocity



- The apparent particle velocity [$V^*(t)$] of the interface is dependent upon the refractive index [$V^*(t)$] = $-\frac{d}{dt}\left(\int_{x(t)}^{xr} n(x',t)\,dx'\right)$
- If LiF follows Gladstone–Dale ($n = a + b\rho$)

$$[V^*(t)] = -\frac{d}{dt}\left[a(x_s/t) - (x/t) + b\int_{x(t)}^{x_s}\rho(x',t)\,dx'\right]$$

Mass conservation

- True particle velocity [$V(t)$] is $V(t) = \frac{V^*(t)}{a}$
- No dependence upon the optical path length in LiF if the behavior follows Gladstone–Dale

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Determination of laser pulse design to maintain shockless compression

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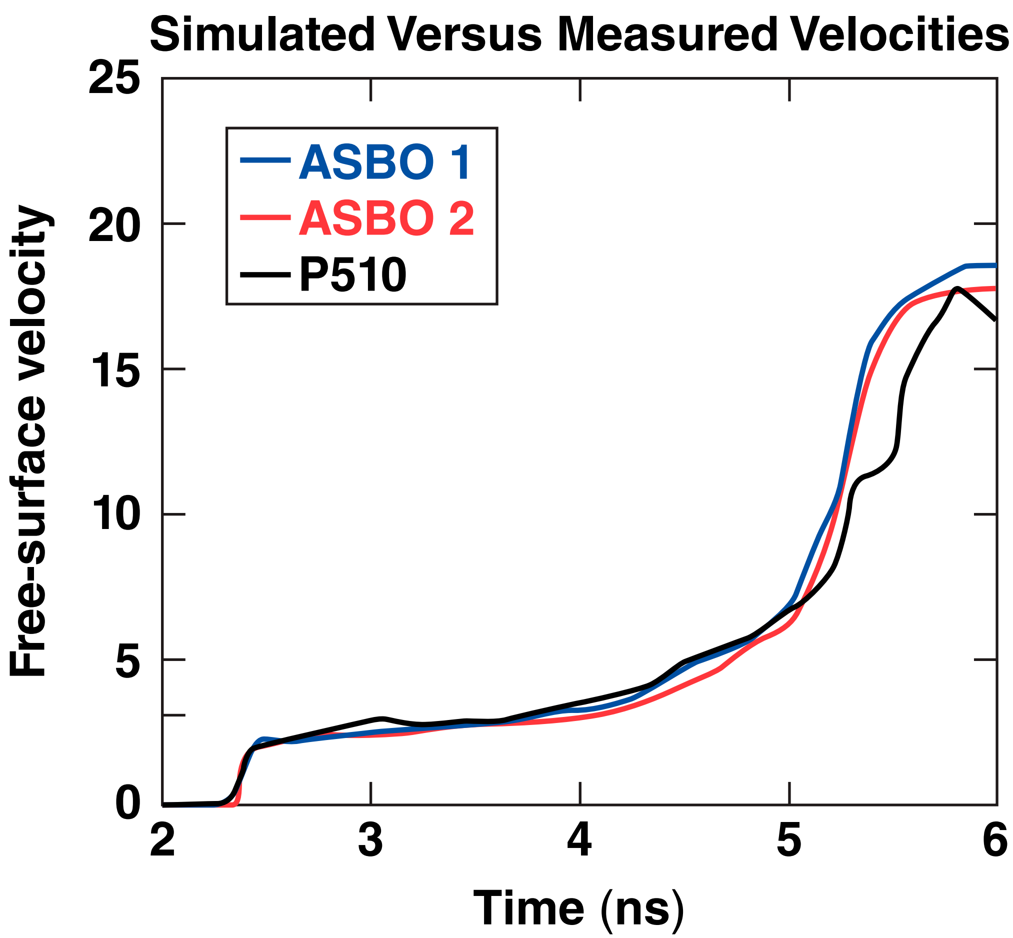

- The requirement for shockless compression over distance x_0 (without reflection)

$$\frac{dP}{dt} < \frac{C_L^2}{x_0} \frac{dP}{C_L}$$

- Pulse profile design is complicated with the inclusion of reflected waves
  - correction for wave interactions*
- Predictions correlate well with experimental data

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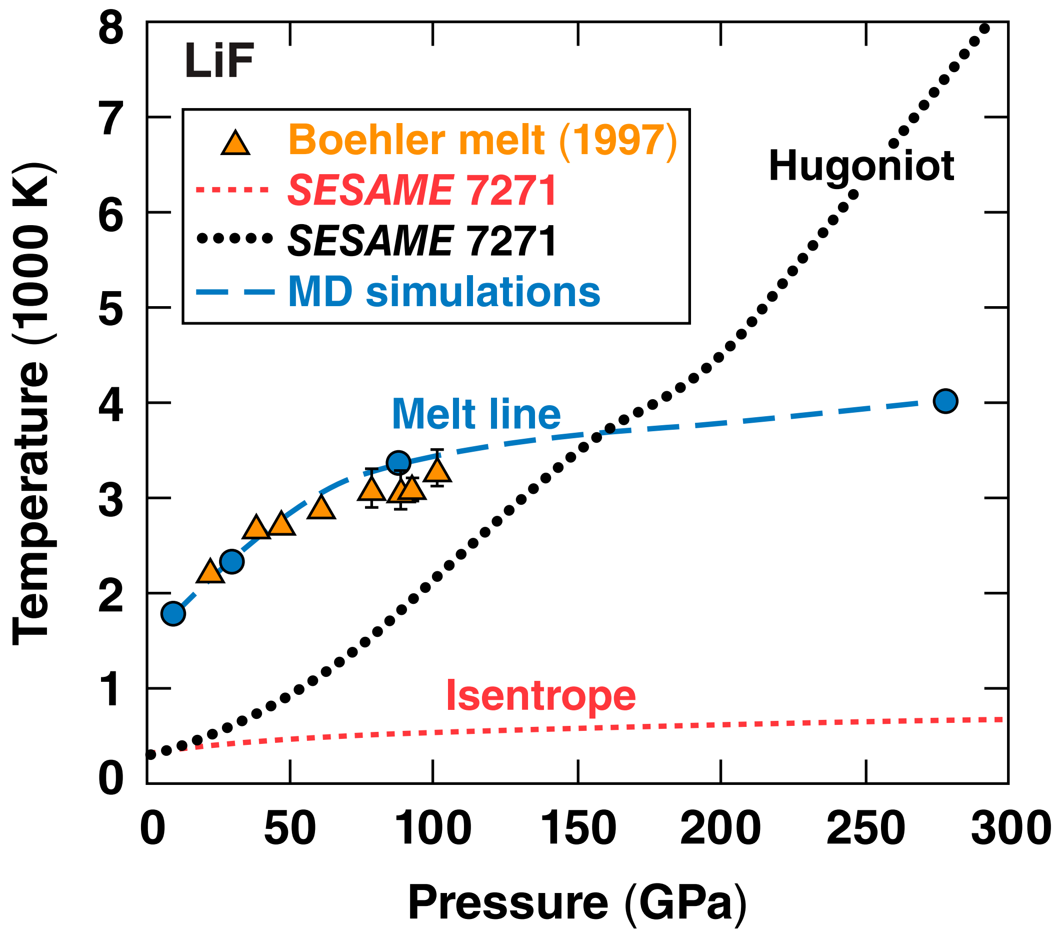
*S. D. Rothman and J. Maw, J. Phys. IV France 134, 745 (2006).

Methods to study the LiF refractive index



- Two methods of study
  - shock compression
  - ramp compression
- Each method makes it possible to study different regions of phase space
- Study whether loading technique affects the index of refraction
- Understand if melt causes LiF window blanking