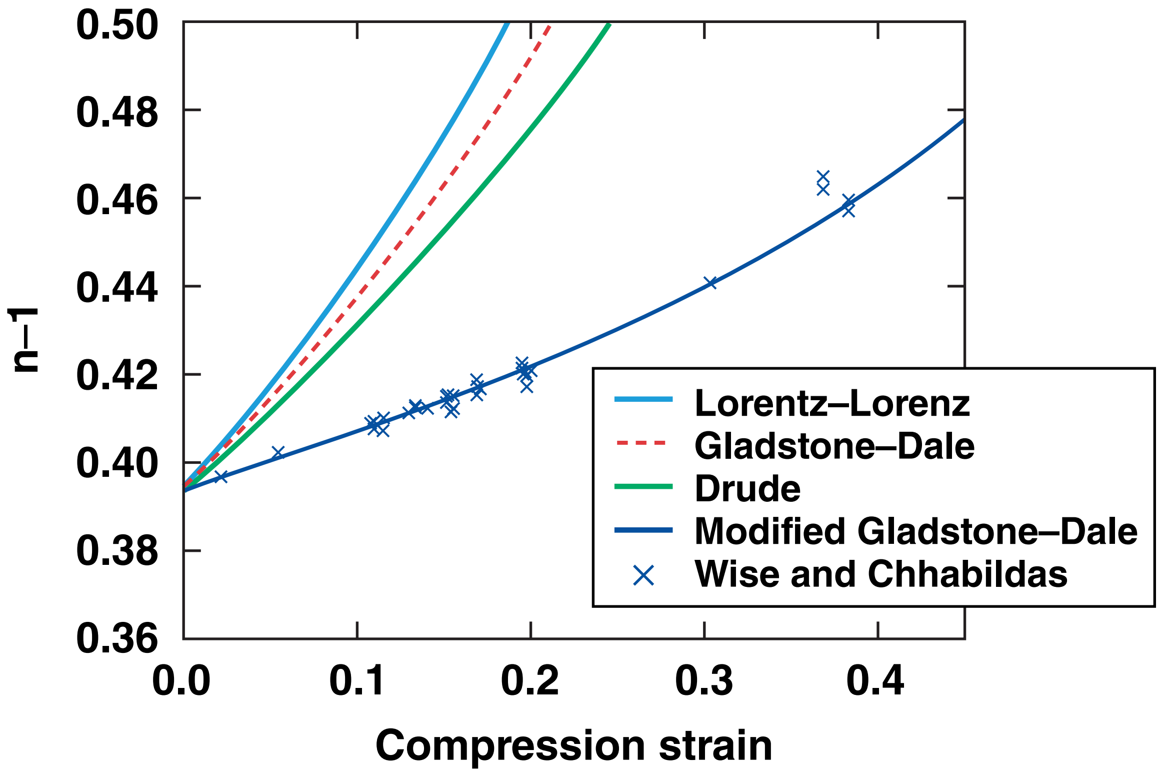
Optical Properties of Compressed LiF



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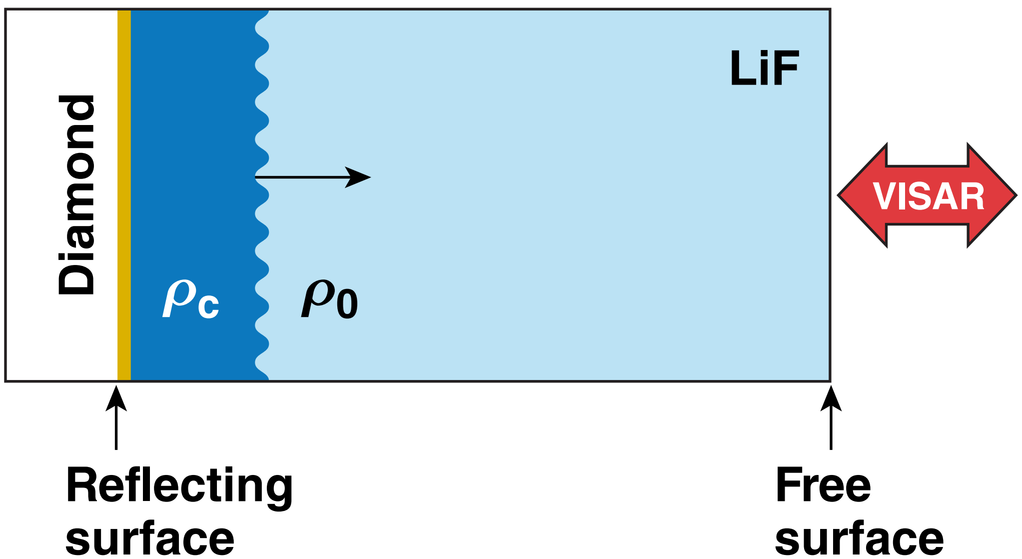
Summary

Goal is to measure refractive index of compressed LiF

- Accuracy of shock compressed and isentropically compressed LiF refractive index to pressures above ~1 Mbar has not been validated
  - important for the accuracy of VISAR measurements
- New techniques to examine the refractive index under
  - shock compression
  - ramp compression
- Proof-of-principle experiments using the Janus Laser Facility have been conducted and correlated with existing data
- Shots have been allocated for future experiments

VISAR velocity corrections for LiF windows



- Doppler shift of reflected light is manifested as a fringe shift in VISAR
- Fringe phase is proportional to the optical path
- Under compression (ρ_c) refractive index can change
- This correction may not be constant

$$V^*(t) = -\frac{d}{dt}\left[\int_{x(t)}^{x_r} n(x',t)\,dx'\right]$$

For linear window materials

$$n = a + b\rho$$

$$V(t) = \frac{V^*(t) + (a-1)V_{FS}(t)}{a}$$

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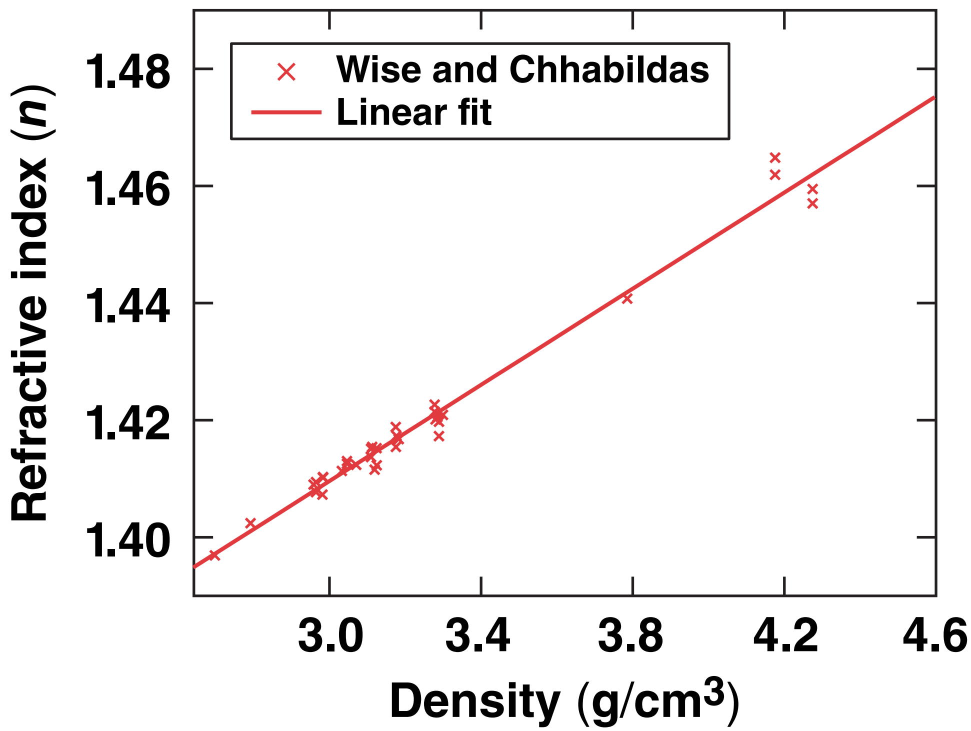
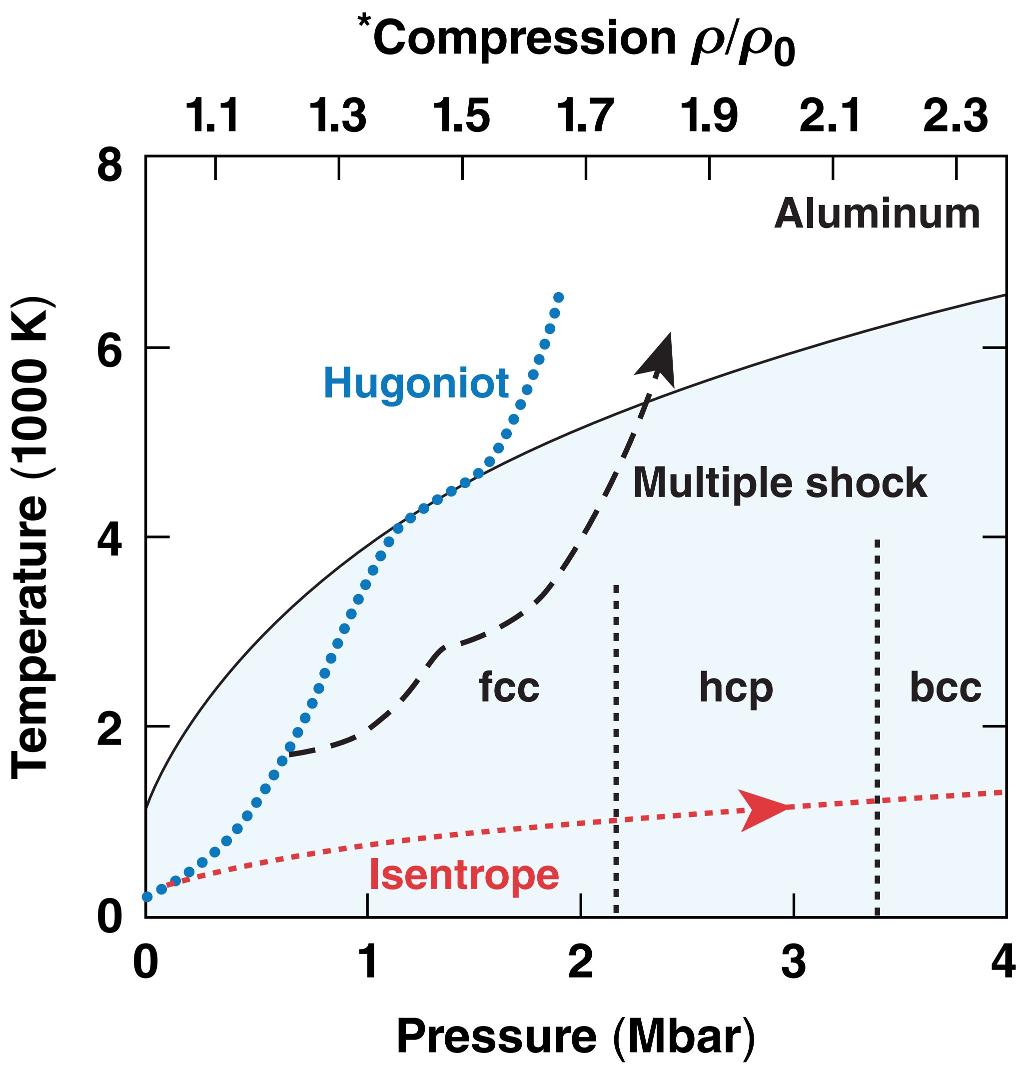
Measurements of the LiF index are extrapolated to higher velocities

LiF refractive index as a function of density



- Shocked LiF has been studied up to ~1.0 Mbar (4.2 g/cm^3)
- VISAR experiments use LiF windows for pressures up to 5 Mbar
- Linear extrapolation is used for higher pressures and density

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

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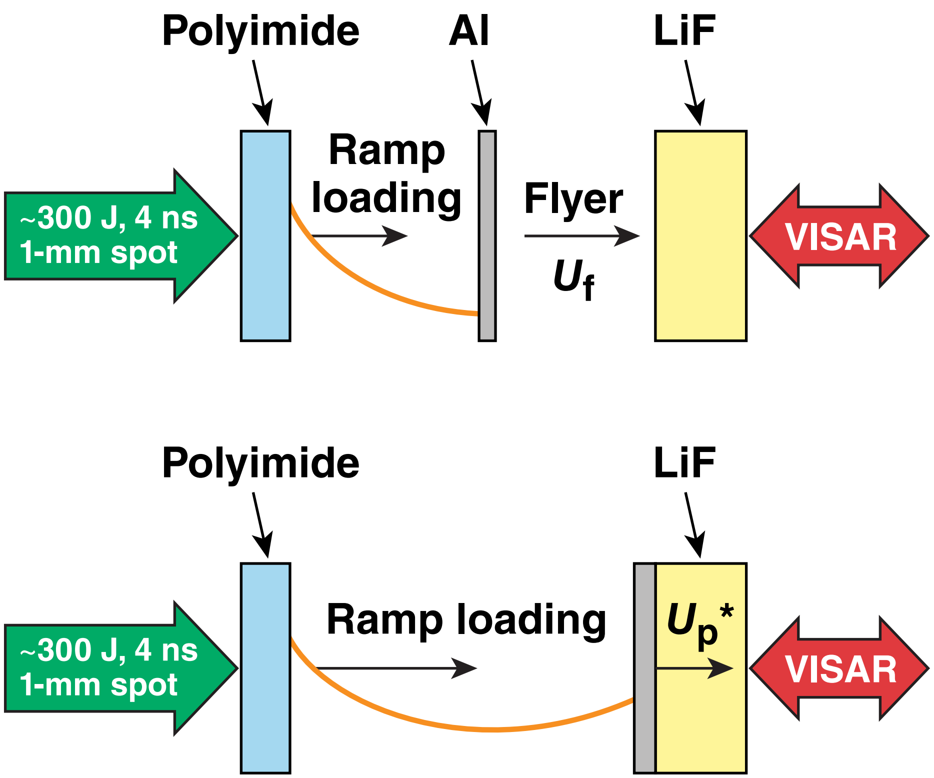
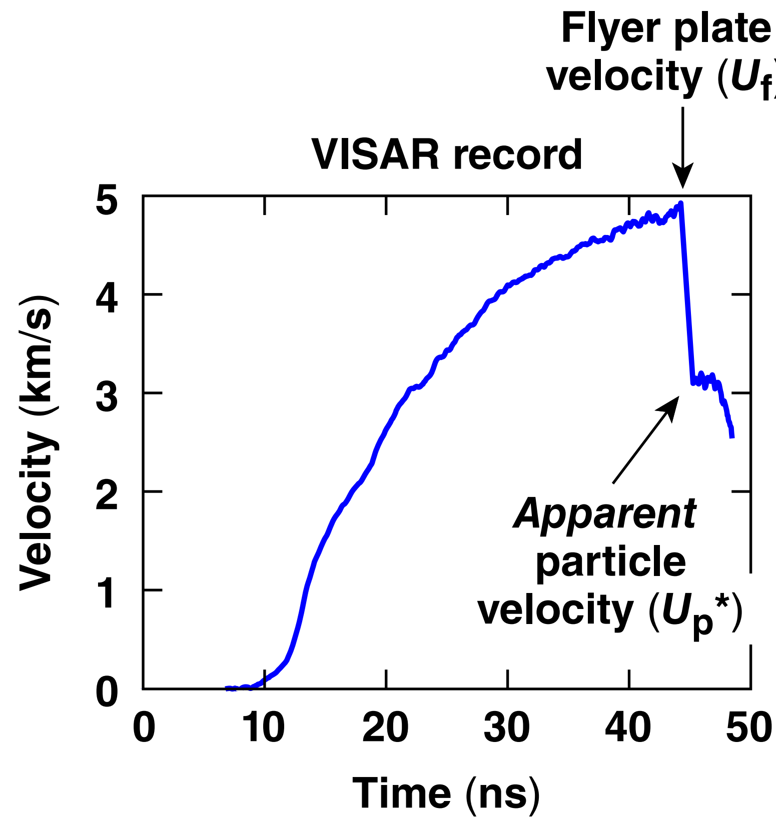
*K. T. Lorenz *et al.*, High Energy Density Phys. 2, 113 (2006).

Proof-of-principle experiments were conducted to measure the refractive index of shock-compressed LiF†





The *apparent* particle velocity (U_p*) measured by VISAR is not an accurate measurement of the particle velocity caused by the LiF refractive index (*n*).

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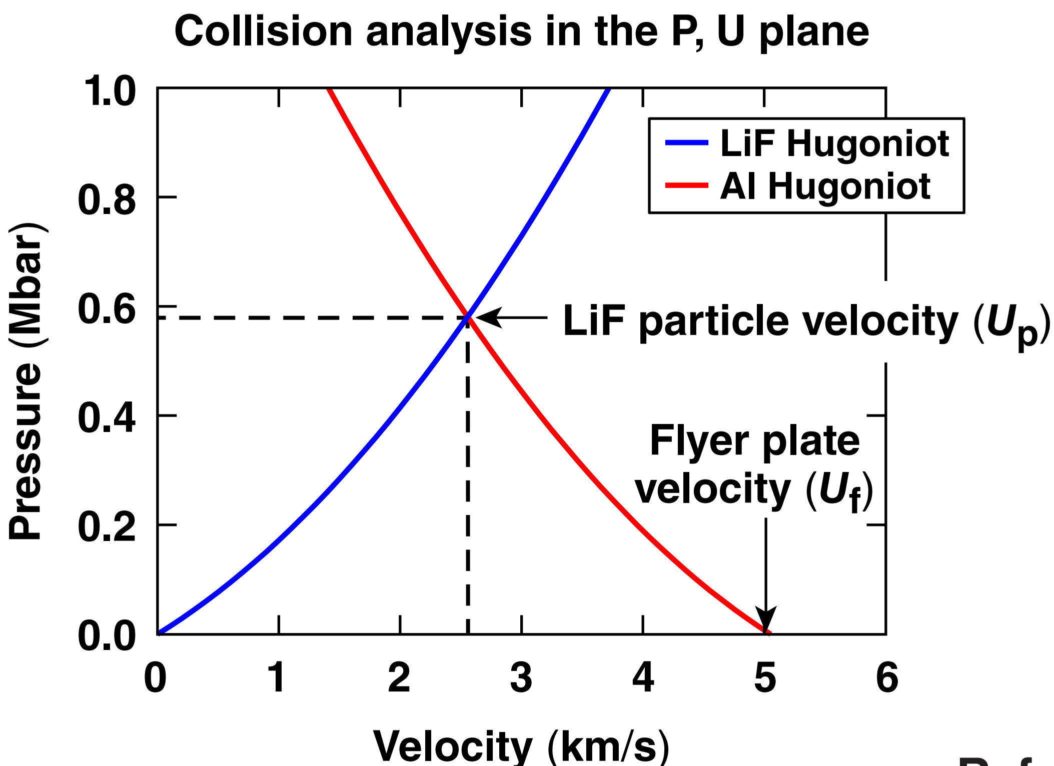
†Experiments were performed by J. Eggert and R. Smith at the Janus Laser Facility.

LiF collision analysis to recover the *absolute* particle velocity (U_p)



- **Absolute particle velocity deduced from flyer plate velocity and EOS of materials**
- **Comparison of the absolute and apparent particle velocity determines the refractive index correction**

Correction factor:

$$\frac{U_p^*}{U_p} = \frac{\Delta\nu}{\nu_0} + 1$$

Refractive index†:

$$n = n_0 \frac{U_s}{U_s - U_p} - \left(1 + \frac{\Delta\nu}{\nu_0}\right)\frac{U_p}{U_s - U_p}$$

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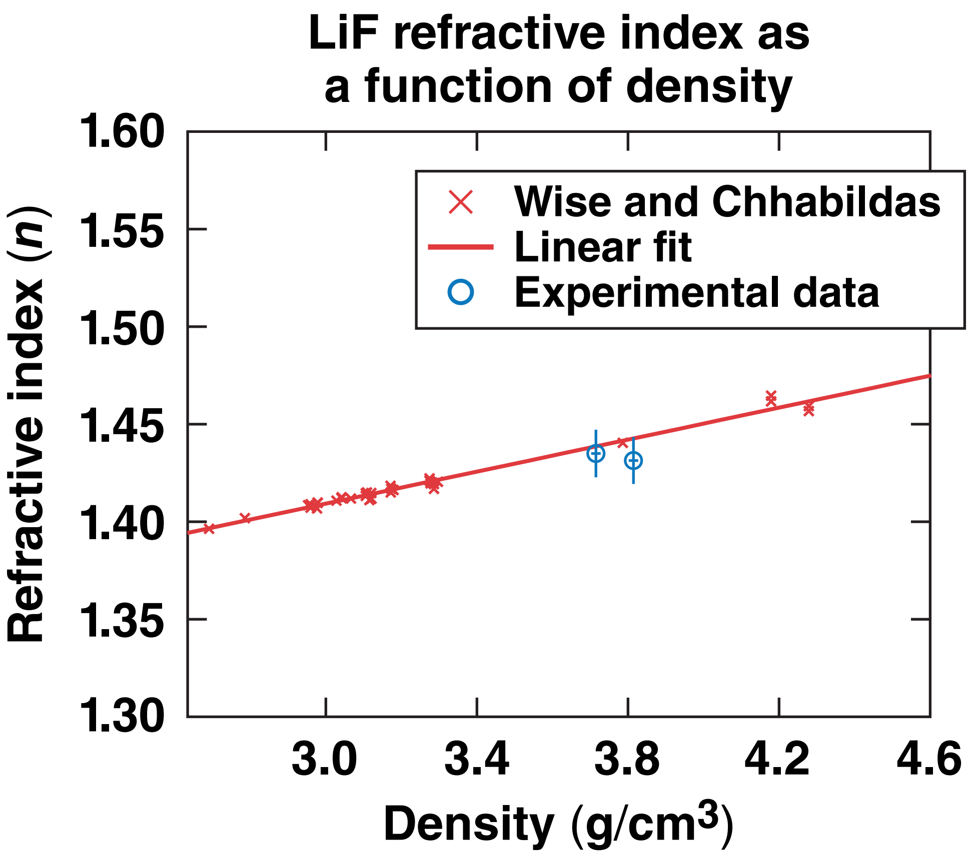
†D. R. Hardesty, J. Appl. Phys. 47, 1994 (1976).

Comparison of proof-of-principle experiments with Wise and Chhabildas gas-gun data



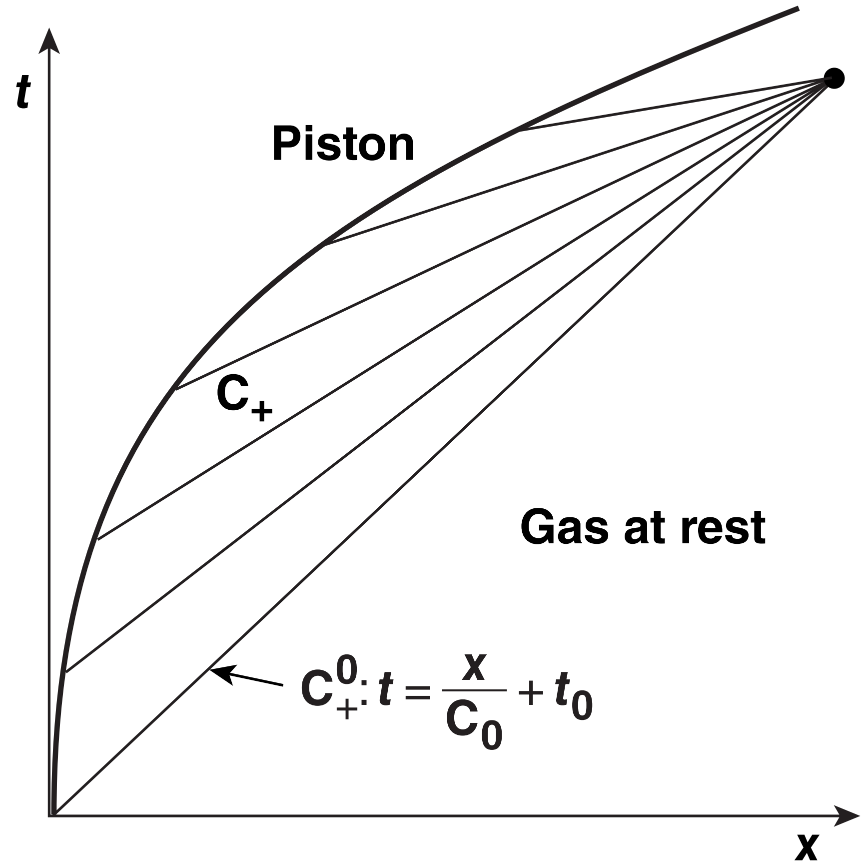
- Correlation between Janus experiments and gas gun
- Extend these shock experiments to higher pressures
- Expect the refractive index of shocked and ramp compressed LiF to differ
- Develop techniques to study ramp compressed LiF

Isentropic compression is a gentle continuous compression of material

- Sound speed in a material increases with compression
- Subsequent compression waves to travel faster than predecessors
- These waves can coalesce, forming a shock
- Design a laser drive that maximizes the applied pressure without forming shock

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

Characteristics of piston/gas*



*R. Courant and K. O. Friedrichs, *Supersonic Flow and Shock Waves*, Corr. 5th print, Applied Mathematical Sciences, v. 21 (Springer-Verlag, New York, 1999).

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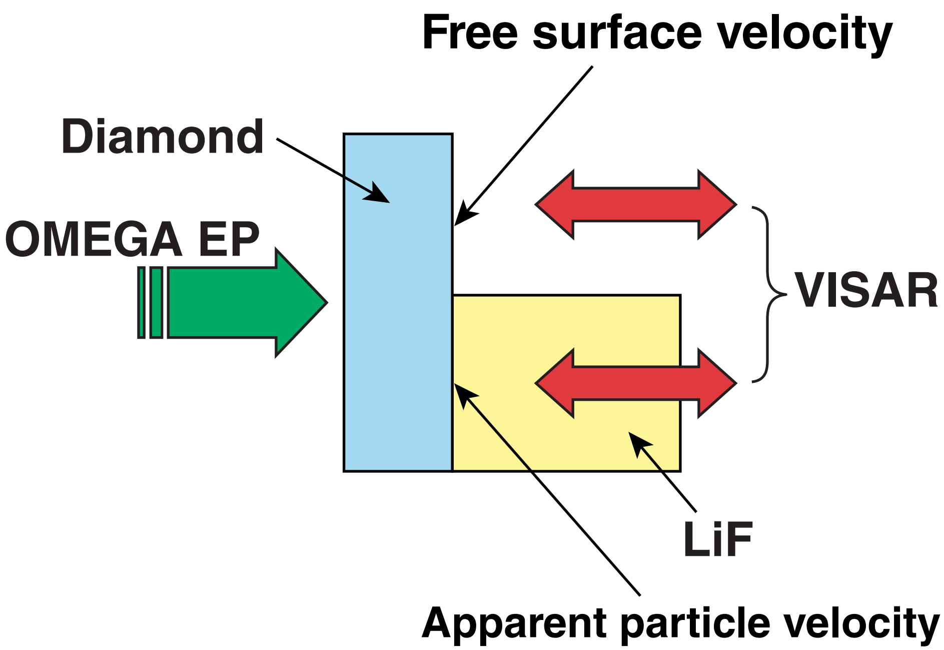
LiF ramp compression target design



- Diamond ablator allows ramp compression to reach high pressure (~5 Mbar) in a short period of time (~10 ns)
- Target design makes it possible to measure both the apparent particle velocity and the free surface velocity simultaneously
- A direct comparison of the free surface velocity and the apparent particle velocity cannot be made
- Backward integration to the loading surface enables the determination of the LiF refractive index

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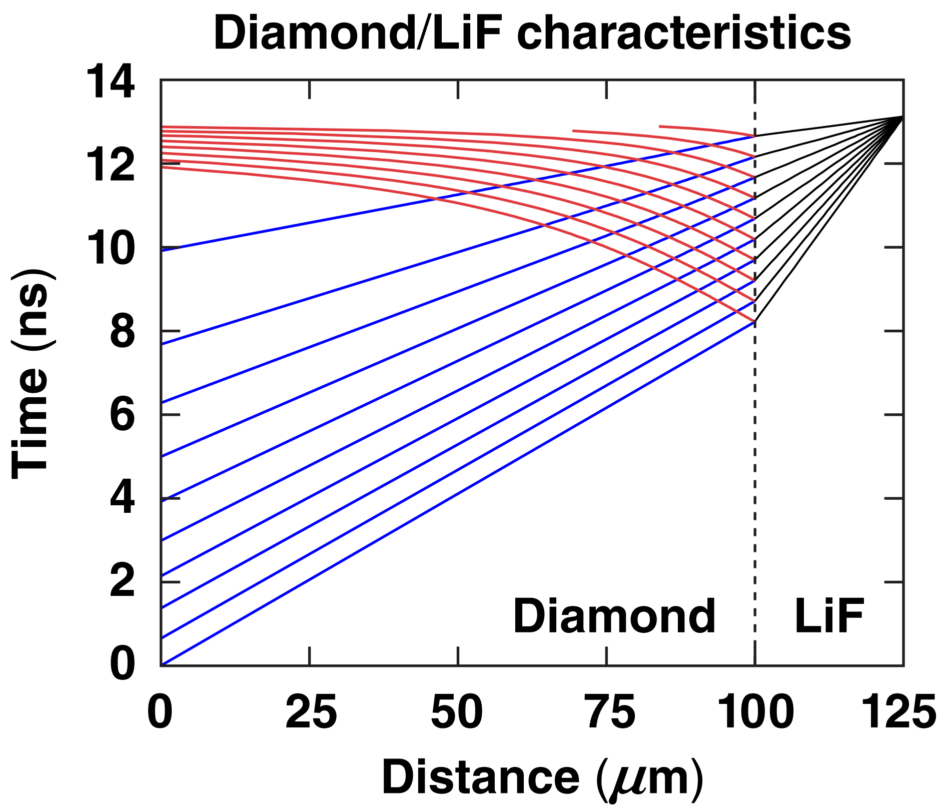
Backward integration to recover the LiF refractive index



Boundary conditions	
Free surface	$P_{\text{Diamond}} = 0$
Interface	$P_{\text{Diamond}} = P_{\text{LiF}}$ $U_{\text{p Diamond}} = U_{\text{p LiF}}$

- VISAR record contains the velocity "boundary conditions"
- Using the EOS of LiF and diamond can backward integrate to the loading surface
- Comparison of the backward-integrated free surface velocity and *apparent* particle velocity makes it possible to recover the refractive index of LiF
- Experiments are planned for the week of 22 June 2009

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Summary/Conclusions

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