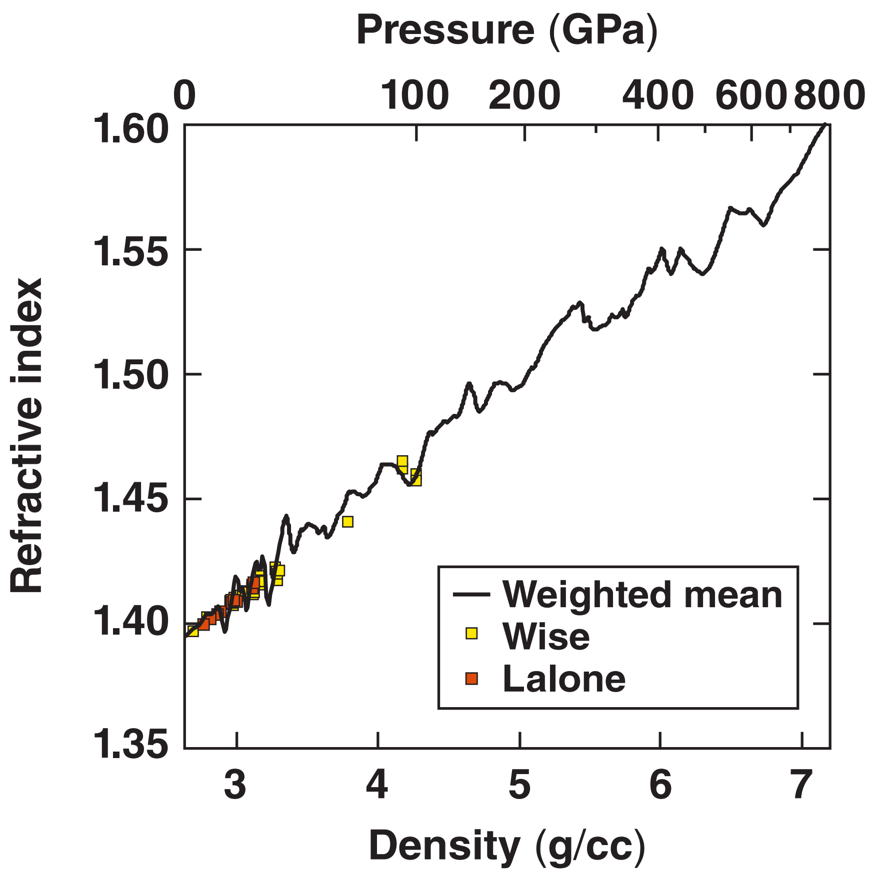
Refractive-Index Measurements of Ramp-Compressed LiF to 800 GPa



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Summary

The refractive index of ramp-compressed LiF depends linearly on density up to 800 GPa

- Knowledge of LiF's compressed index of refraction is important for high-pressure EOS measurements
- The refractive index of shock compressed LiF has previously been measured to 115 GPa*
- Ramp-compressed LiF is measured up to 800 GPa
  - LiF is observed to remain transparent over this range
- A single-oscillator model suggests that the band gap will close at pressures above 4200 GPa
  - These are the highest refractive-index measurements of an insulator ever made.

J. L. Wise and L. C. Chhabildas, Sandia National Laboratory, Report SAND-85-0310C, NTIS (1985).

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Collaborators

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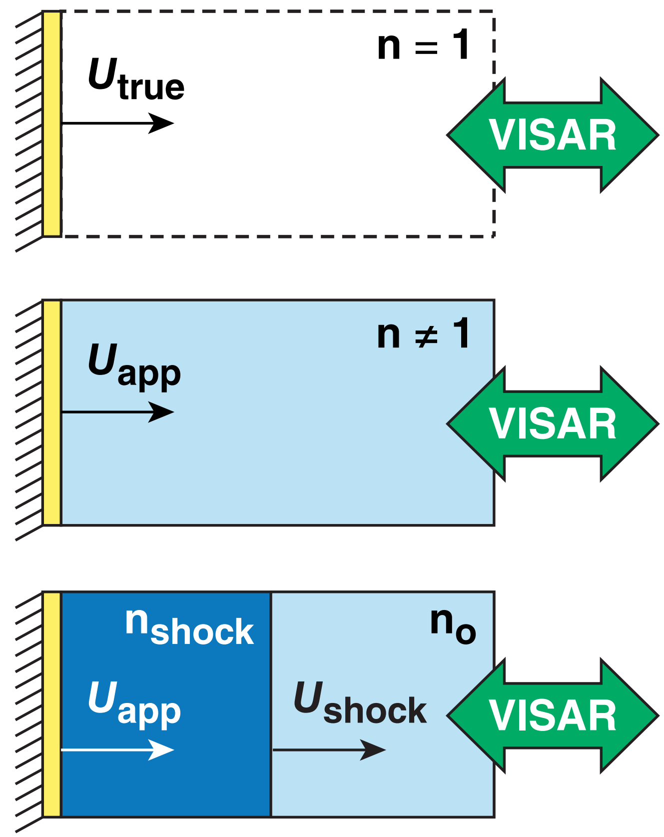
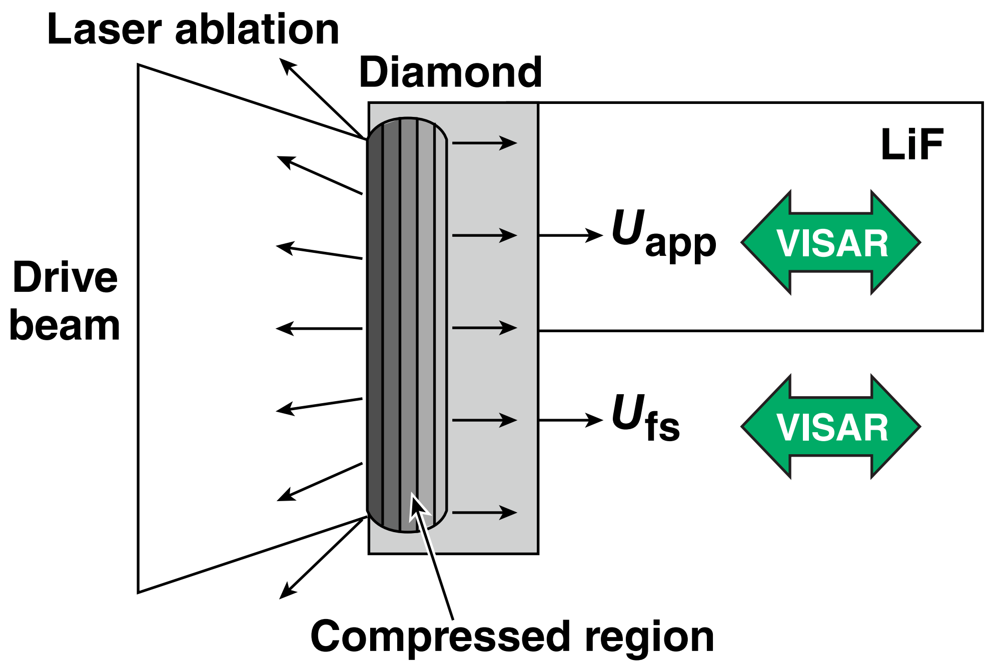
The refractive index of optical windows affects VISAR velocity measurements

- VISAR detects Doppler shifts from moving surfaces
- Optical windows influence the Doppler shift
- Changes to the window alter the optical path length of the probe beam
- The refractive index is determined if the apparent velocity (U_{app}) and the *true* velocity (U_{true}) are known



A two-section target enables one to simultaneously measure the apparent and true particle velocity



- Hayes* showed that for ramp compression,

$$\frac{dU_{app}}{dU_{true}} = n - \rho \frac{dn}{d\rho}$$

- U_{app} is measured directly
- U_{fs} is backward integrated to determine the ablation pressure
- The ablation pressure is forward integrated to determine U_{true}

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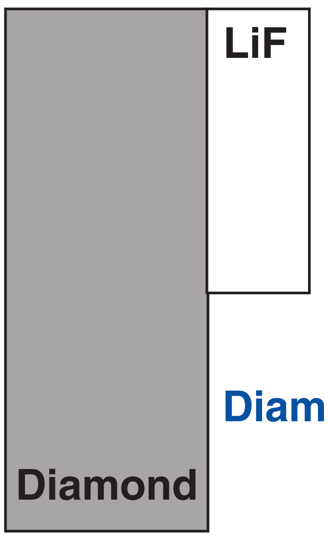
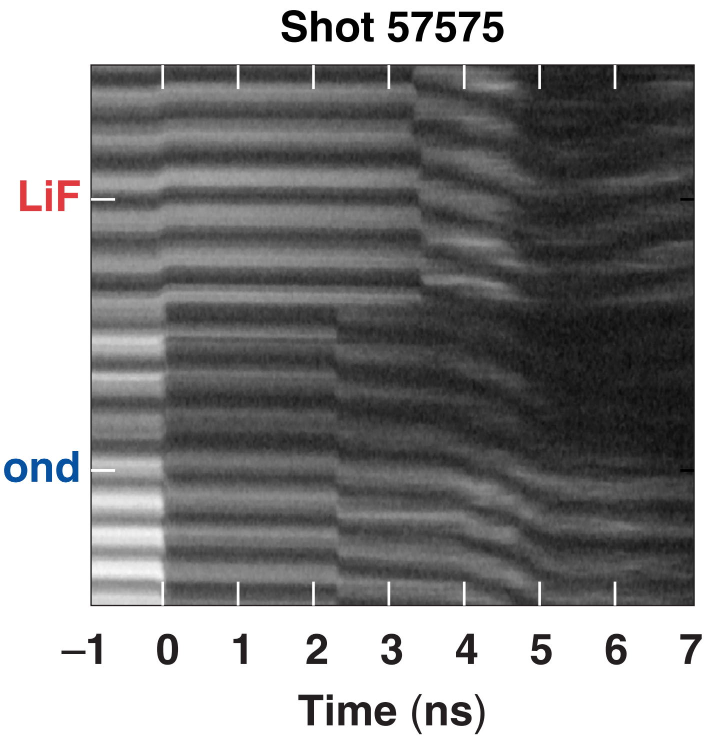
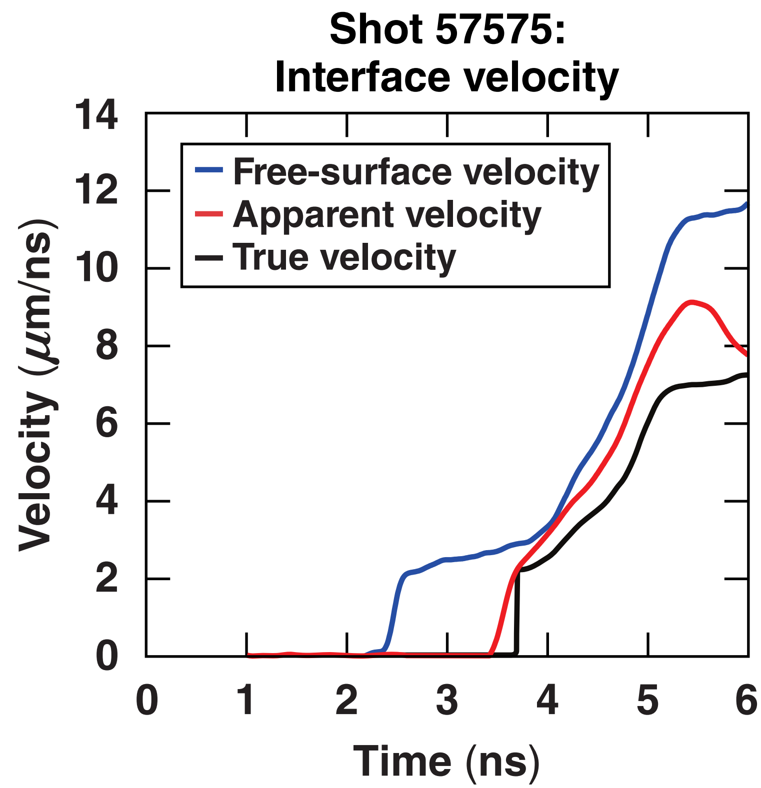
*D. Hayes, J. Appl. Phys. 89, 6484 (2001).

Diamond-free surface and apparent interface velocity are measured simultaneously with VISAR[1] on OMEGA







- The true particle velocity is determined from the method of characterisitcs[2]

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[1]P. M. Celliers *et al.*, Rev. Sci. Instrum. 75, 4916 (2004).
[2]D. E. Fratanduono *et al.*, "Refractive Index of Lithium Fluoride at Pressures up to 800 GPa," submitted to Physical Review Letters.

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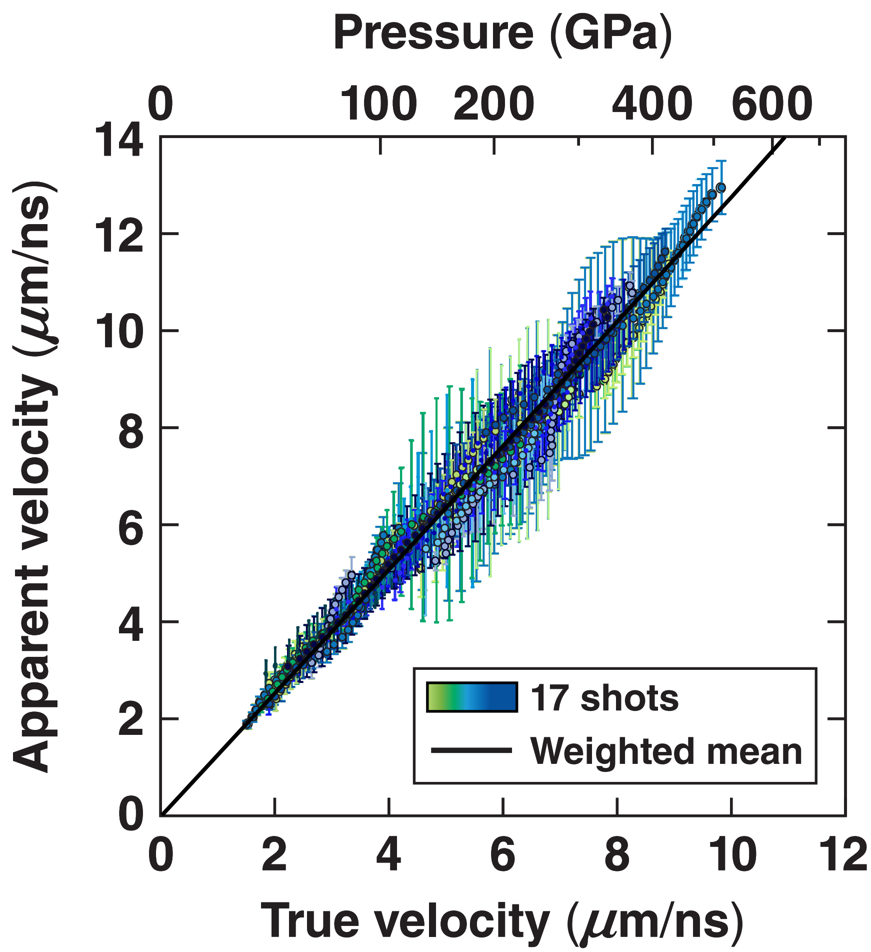
The apparent velocity depends linearly on the true particle velocity

- A second-order, orthogonal-polynominal regression determines the relation between the apparent- and true particle velocity:

$$U_a(U_T) = a_o + a_1(U_T - \beta) + a_2(U_T - \gamma_1)(U_T - \gamma_2)$$

$$U_a(U_T) = 3.06 + 1.275(\pm 0.008)(U_T - 2.41) + 0.008(\pm 0.002)(U_T - 0.713)(U_T - 9.53)$$



A linear dependence on refractive index is observed

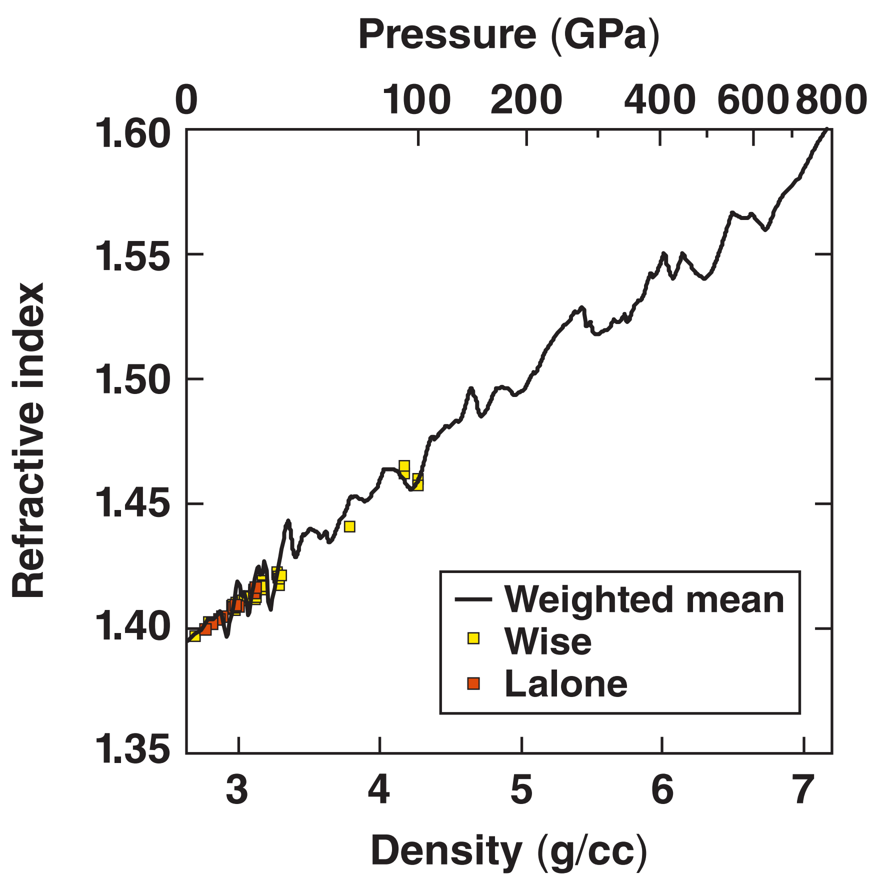
- **Refractive index is determined from Hayes formula***

$$\frac{dU_{app}}{dU_{true}} = n - \rho \frac{dn}{d\rho}$$

- **For linear U_{app} (U_{true})**

$$n = a + b\rho$$

$$n = 1.2751\ (\pm 0.0082) + 0.0440\ (\pm 0.0022)\ \rho$$

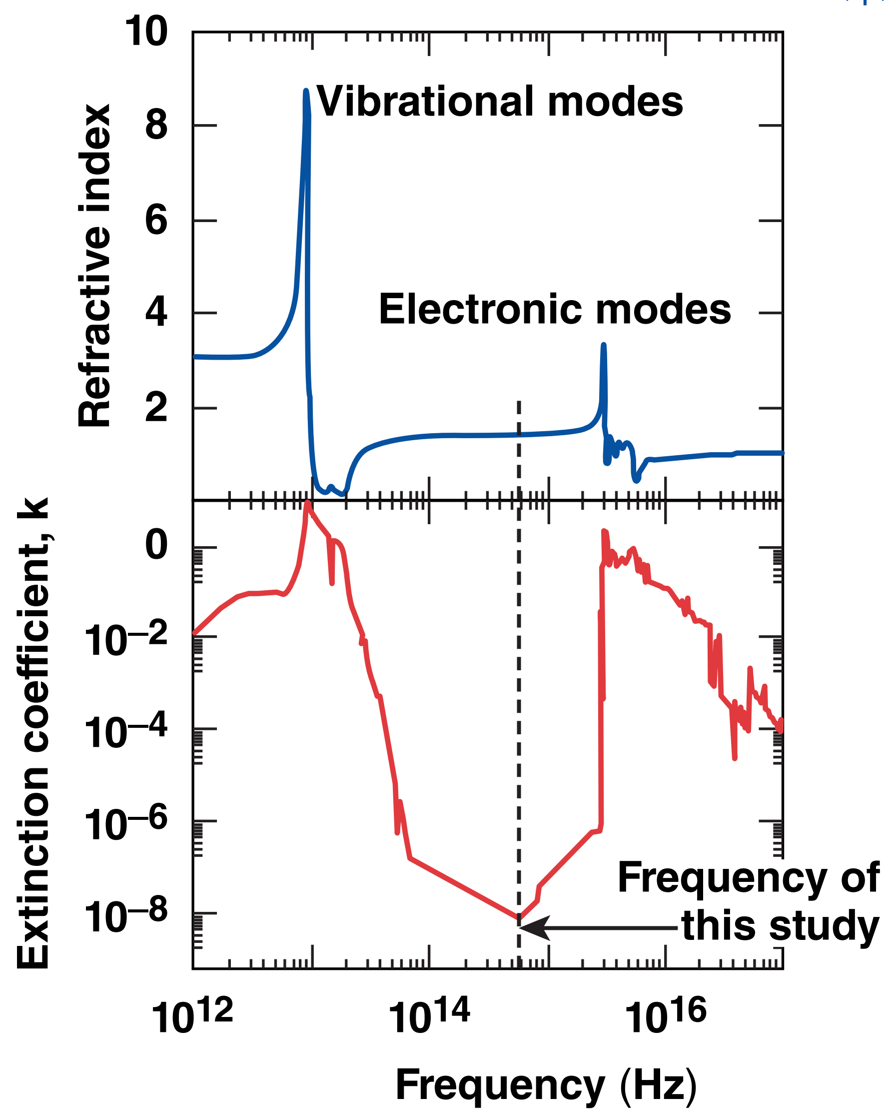


*D. Hayes, J. Appl. Phys. 89, 6481 (2001).

An effective oscillator model is used to interpret the linear dependence of the refractive index and density

- Only electronic excitations are considered
  - Probe frequency is above the vibrational modes

- Changes in the refractive index related to increases in density are caused by a shift in the electronic resonance to lower frequency



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E. Palik, Handbook of Optical Constants of Solids, New York Academic Press (1985).

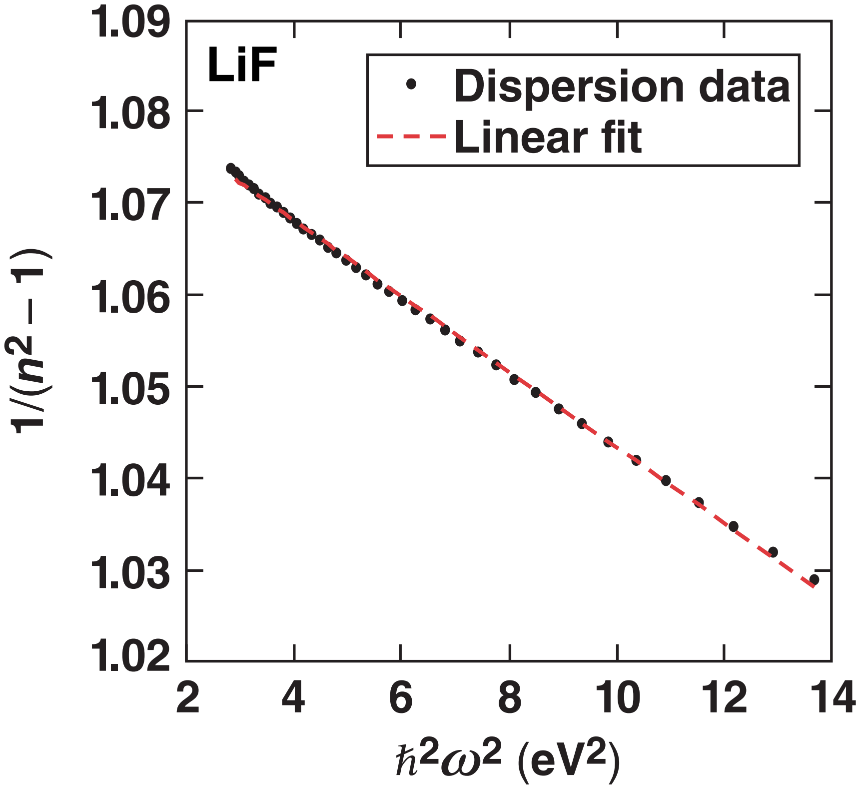
Single oscillator model accurately describes the dispersion of the refractive index

- Over 100 solid and liquid insulators obey this model

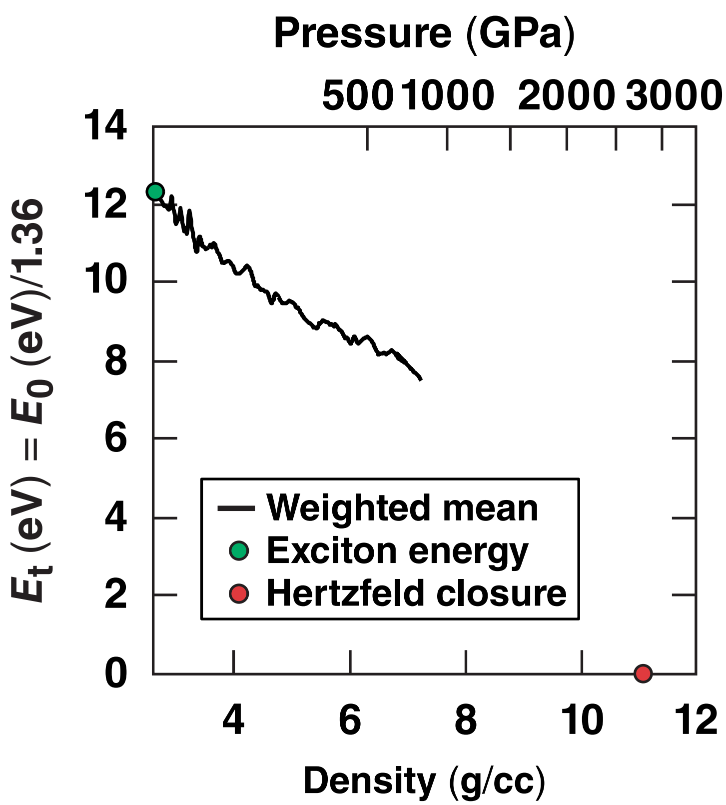
$$n^2 - 1 = \frac{E_d E_0}{E_0^2 - \hbar^2 \omega^2}$$

  - E_d is the dispersion energy
  - E_0 is the single oscillator energy
    - for the alkali-halides, E_0 is related to the excitonic energy (E_T) by $E_0 \simeq 1.36\ E_T$

- Previous studies on compressed H_2 and H_2O to hundreds of GPa have shown that E_d is insensitive to changes in density



An effective oscillator model suggests LiF will remain transparent to pressures above 4200 GPa



Extrapolation of these results suggests metallization will occur at ~ 4200 GPa.

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Summary/Conclusions

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