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

D. E. Fratanduono
University of Rochester
Laboratory for Laser Energetics

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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.

Collaborators

M. A. Barrios, T. R. Boehly, D. D. Meyerhofer
Laboratory for Laser Energetics
University of Rochester

J. H. Eggert, D. G. Hicks, R. Smith,
P. M. Celliers, R. Rygg, G. W. Collins
Lawerence Livermore National Laboratory
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 \( U_{\text{app}} \) and the true velocity \( U_{\text{true}} \) are known
A two-section target enables one to simultaneously measure the apparent and true particle velocity.

• Hayes* showed that for ramp compression,
  \[
  \frac{dU_{\text{app}}}{dU_{\text{true}}} = n - \rho \frac{dn}{d\rho}
  \]
  
  • $U_{\text{app}}$ is measured directly
  • $U_{fs}$ is backward integrated to determine the ablation pressure
  • The ablation pressure is forward integrated to determine $U_{\text{true}}$

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Diamond-free surface and apparent interface velocity are measured simultaneously with VISAR\textsuperscript{1} on OMEGA

- The true particle velocity is determined from the method of characteristics\textsuperscript{2}

\begin{itemize}
  \item D. E. Fratanduono \textit{et al.}, “Refractive Index of Lithium Fluoride at Pressures up to 800 GPa,” submitted to Physical Review Letters.
\end{itemize}
The apparent velocity depends linearly on the true particle velocity

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

\[ U_a(U_T) = a_0 + a_1(U_T - \beta) + a_2(U_T - \gamma_1)(U_T - \gamma_2) \]

\[ U_a(U_T) = 3.06 + 1.275(\pm 0.008)(U_T - 2.41) + 0.008(\pm 0.002)(U_T - 0.713)(U_T - 9.53) \]
A linear dependence on refractive index is observed.

- Refractive index is determined from Hayes formula:
  \[ \frac{dU_{\text{app}}}{dU_{\text{true}}} = n - \rho \frac{dn}{d\rho} \]

- For linear \( U_{\text{app}} \) (\( U_{\text{true}} \))
  \[ n = a + b\rho \]

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

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

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 \( E_0 \approx 1.36 \ E_T \)
- Previous studies on compressed \( \text{H}_2 \) and \( \text{H}_2\text{O} \) to hundreds of GPa have shown that \( E_d \) is insensitive to changes in density

\[ \frac{1}{n^2 - 1} \]

![Graph](image)
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.
Summary/Conclusions

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