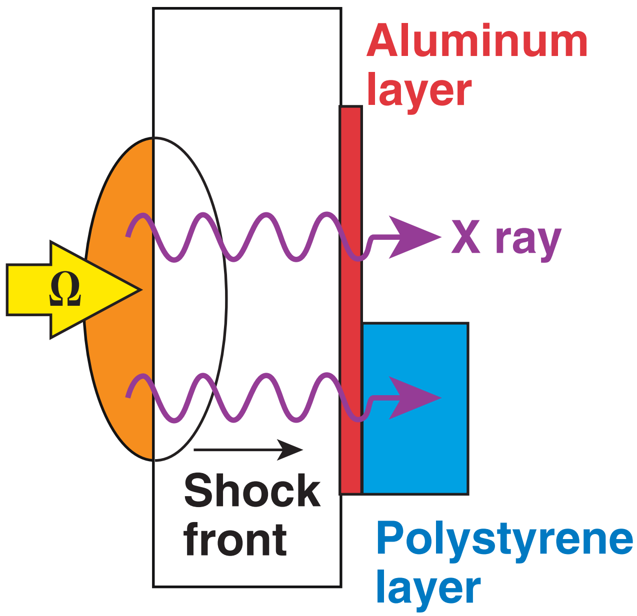
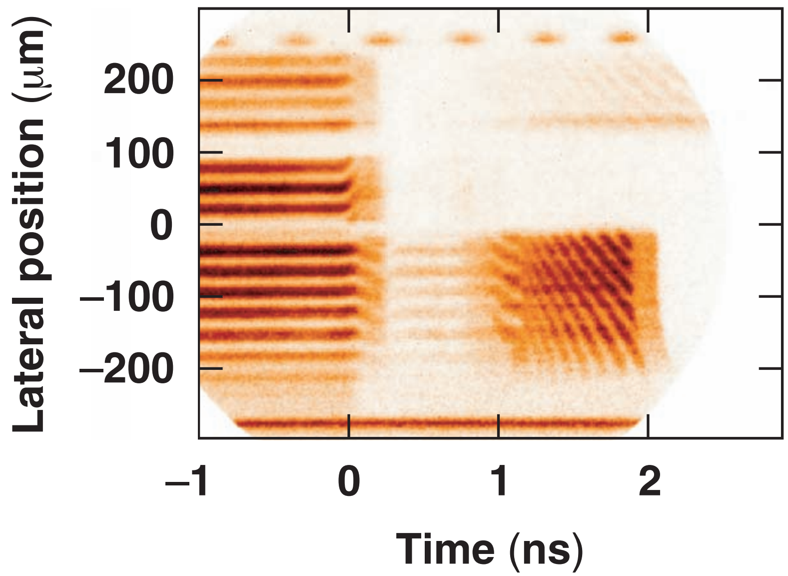
# Optical Measurements of Preheated Polystyrene and Aluminum Layers

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# Collaborators


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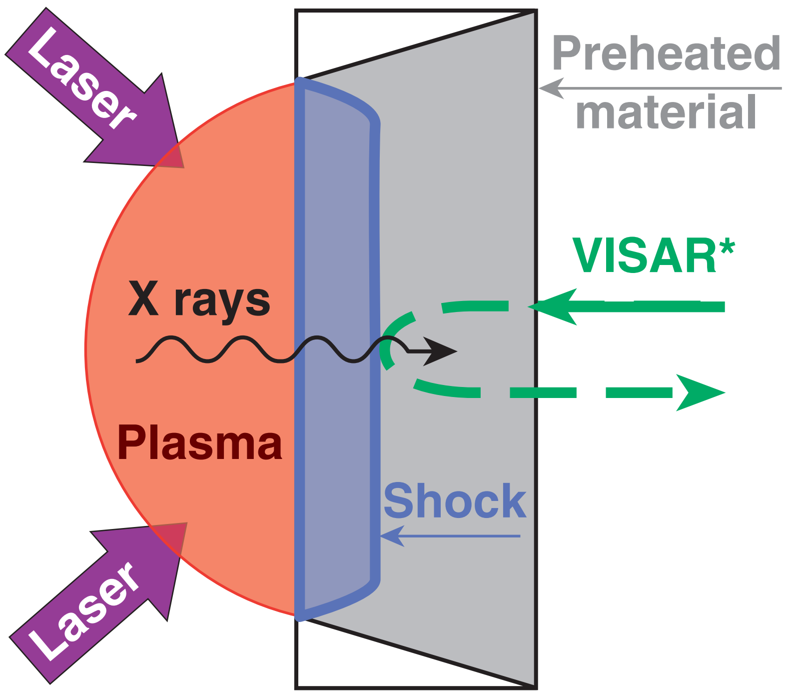
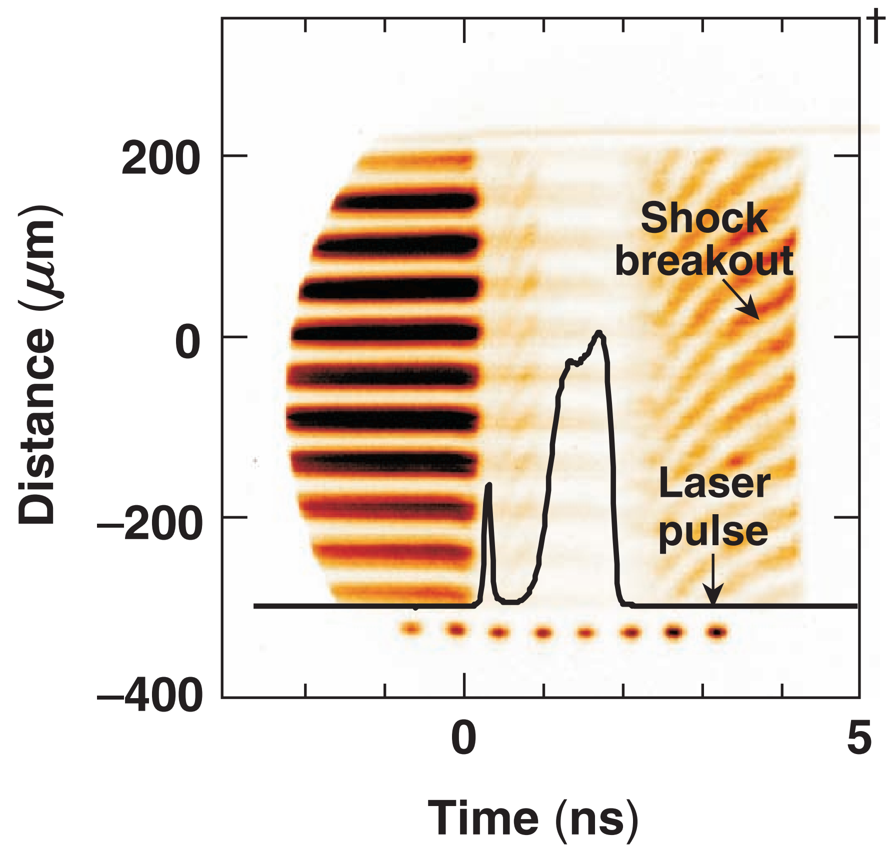
Summary

# Preheating leads to a strong absorption and frequency shift of an optical-probe laser

- X-ray preheating can compromise shock-timing (VISAR) measurements at high laser intensities.
- Preheat experiments using 100-ps laser pulses and planar CH targets revealed a preheat precursor of up to ~4 eV at $5 \times 10^{14}$ W/cm$^2$.
- The expansion of an aluminum layer because of preheat is inferred from a Doppler blue-shifted probe-laser wavelength.
- Preheated polystyrene leads to a strong absorption and a temporally increasing refractive index.

# X-ray preheating can compromise the optical shock-timing diagnostics



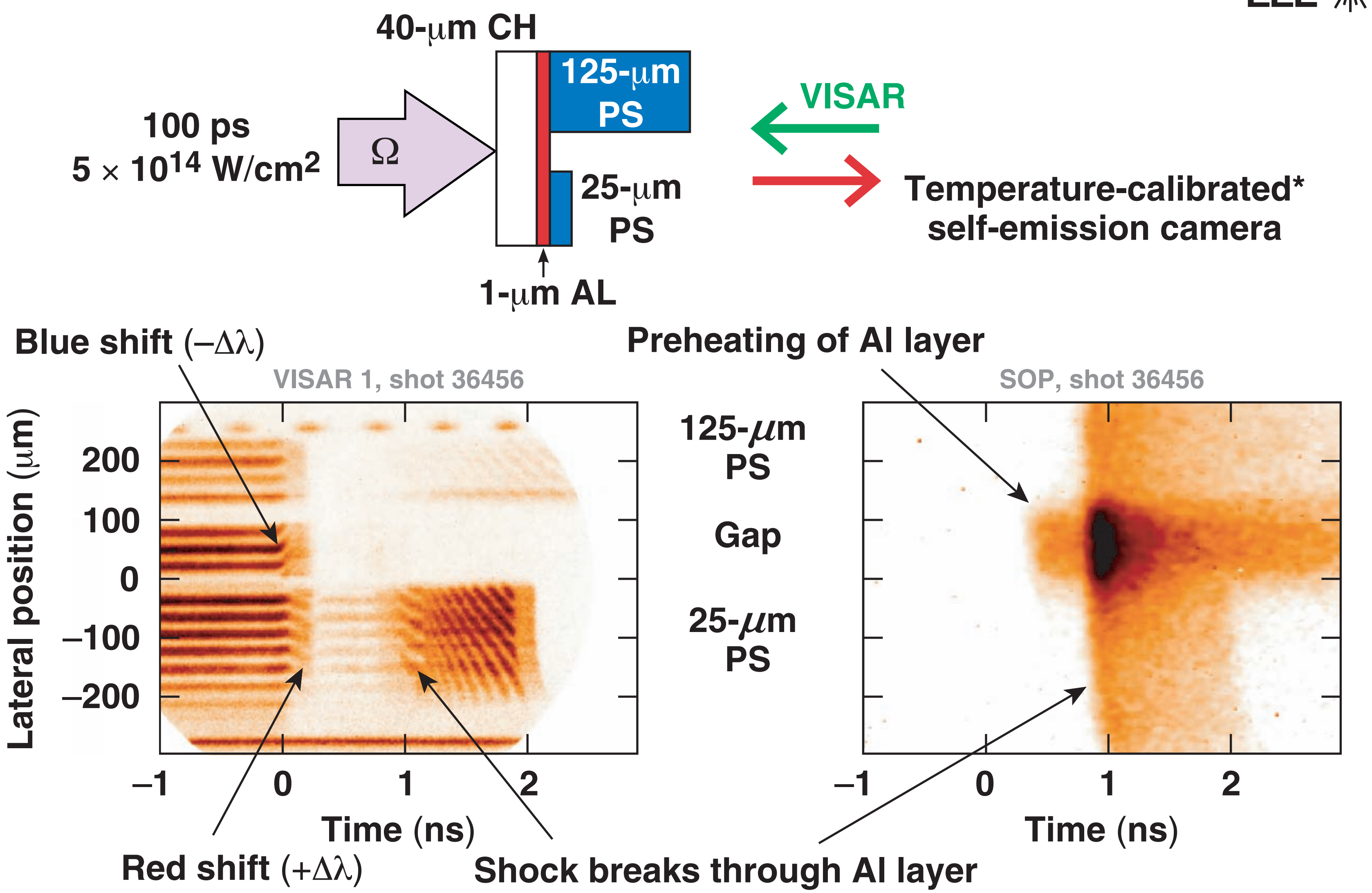




*P. M. Celliers *et al*., Rev. Sci. Instrum. 75, 4916 (2004).

†T. R. Boehly C12.005

E12366d

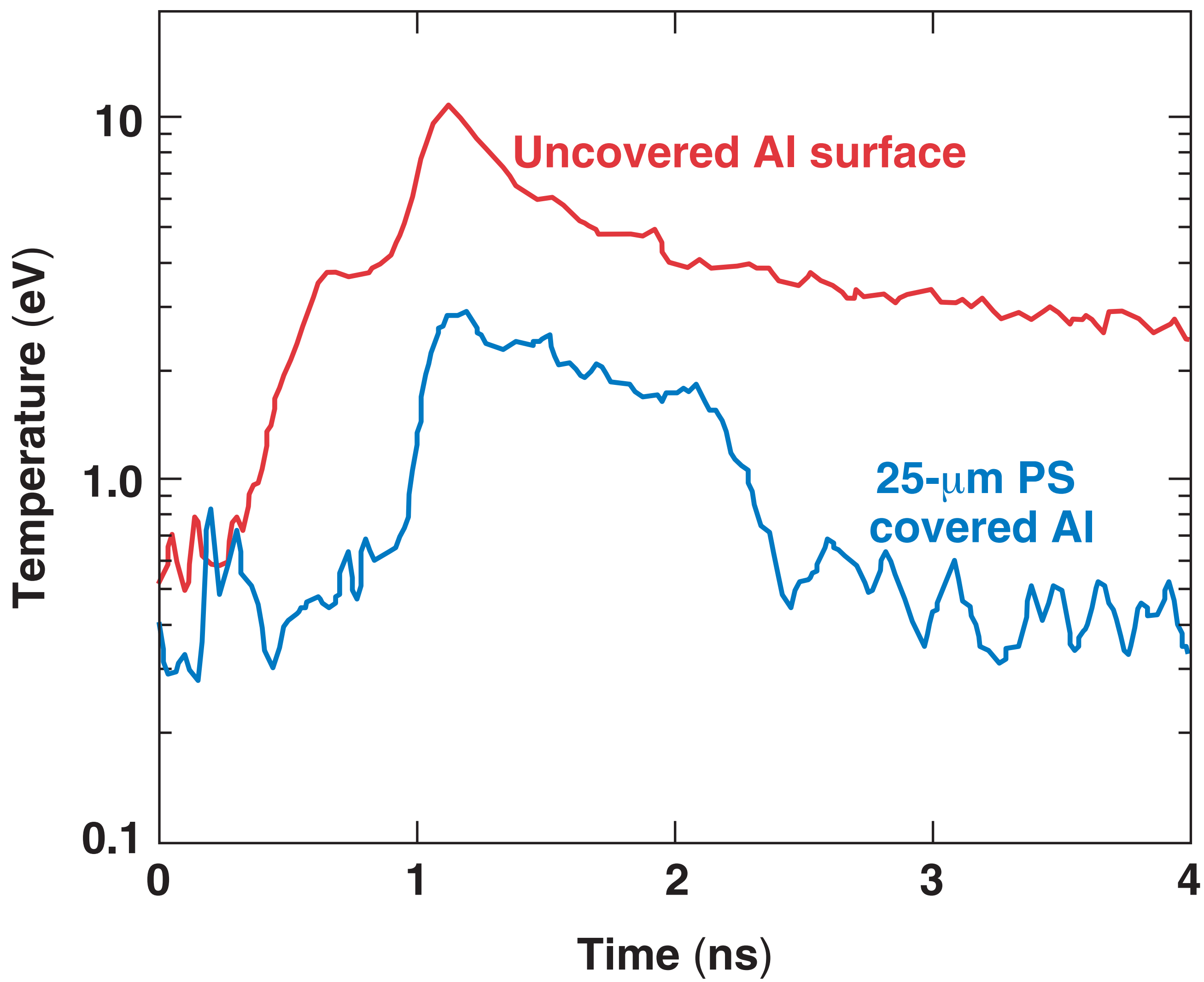
# Strong absorption and wavelength shifts are measured in preheated polystyrene and aluminum




E13837a

*J. Miller, Bull. Am. Phys. Soc. 49, 181, 2004

# Preheating of up to ~ 4 eV is measured prior to the shock front at the target back side

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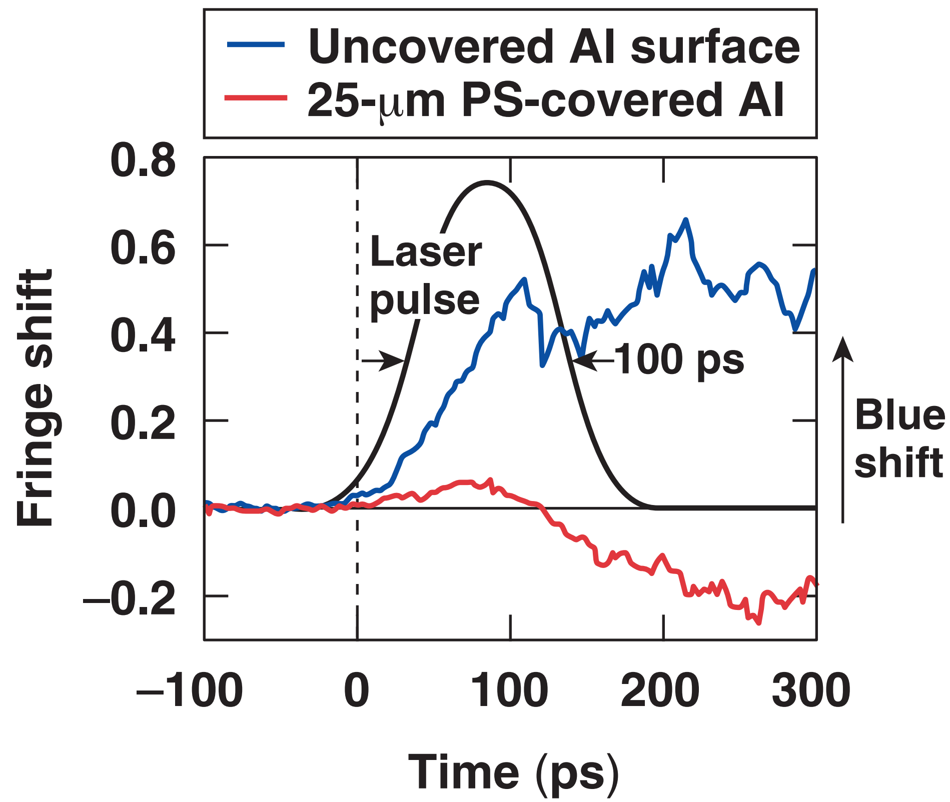
# The expansion of the aluminum layer due to preheat is inferred from a Doppler blue-shifted probe-laser wavelength




Probe beam frequency

$$\omega(t) = \omega_0 - 2k_0 \frac{\partial}{\partial t}(nL)$$

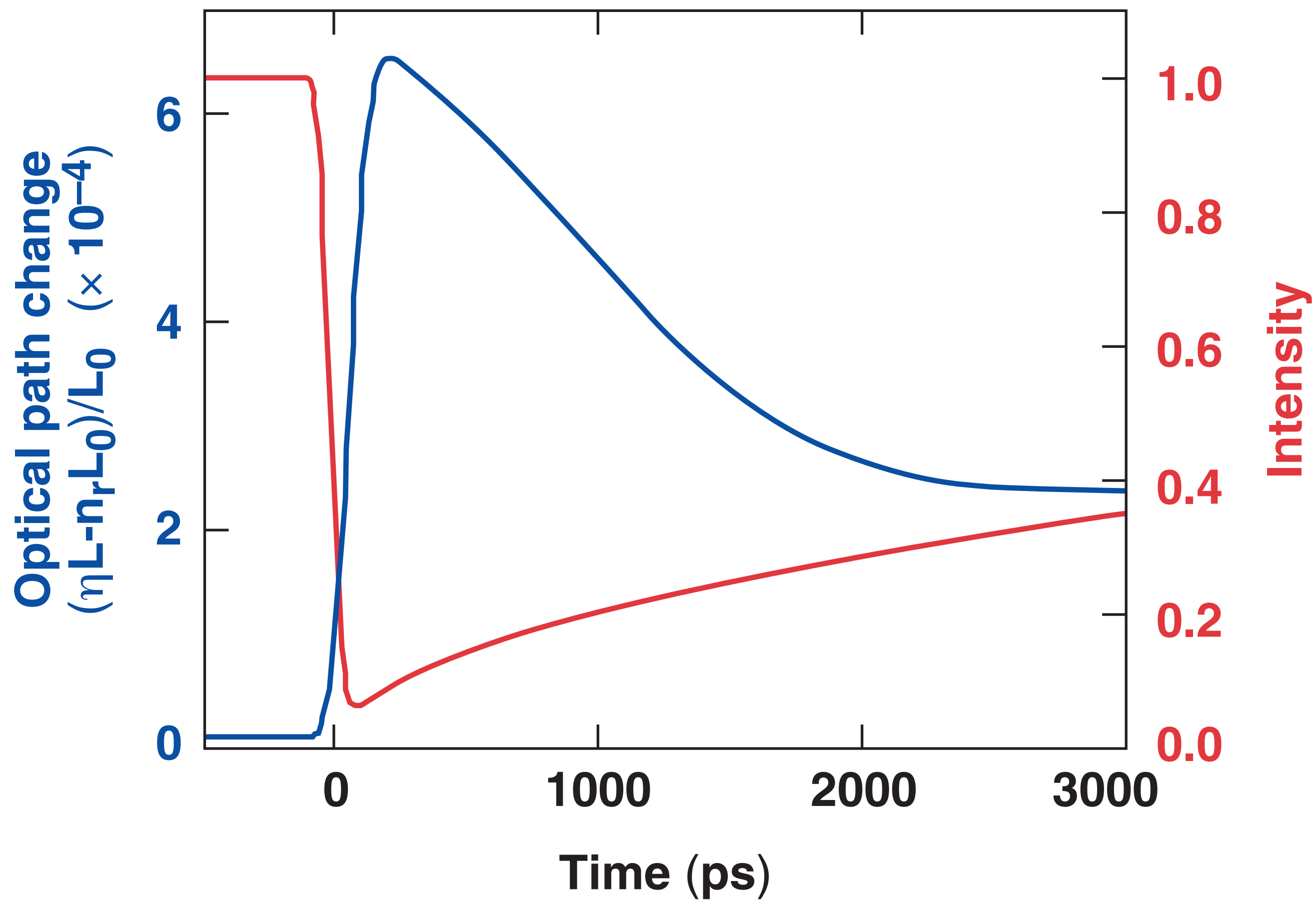
Moving mirror (if n = const.)

$$\Delta f(t) = -\frac{2n}{\lambda_0} \int_{t-\tau}^{t} v(t')dt'$$

- Expansion toward the probe laser [v(t) < 0] results in a blue shift ⇒ + $\Delta f$.
- Ionization (dn/dt < 0) also leads to a blue shift ⇒ + $\Delta f$.

E13839a

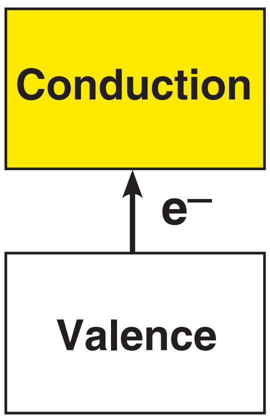
# An increasing refractive index with time is measured for preheated polystyrene




**An additional experiment confirms no measurable thermal expansion of polystyrene (dL/dt = 0)**

E13842a

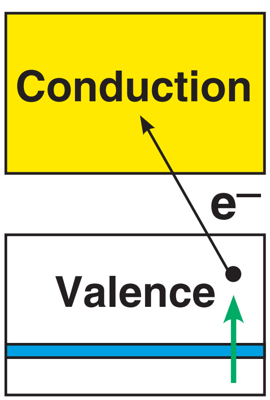
# Ionization by x-rays creates "free" electrons and in some materials optical transitions in the valence band




$$n \approx \sqrt{n_r^2 - \frac{\omega_p^2}{\omega_0^2 + \nu^2}}$$

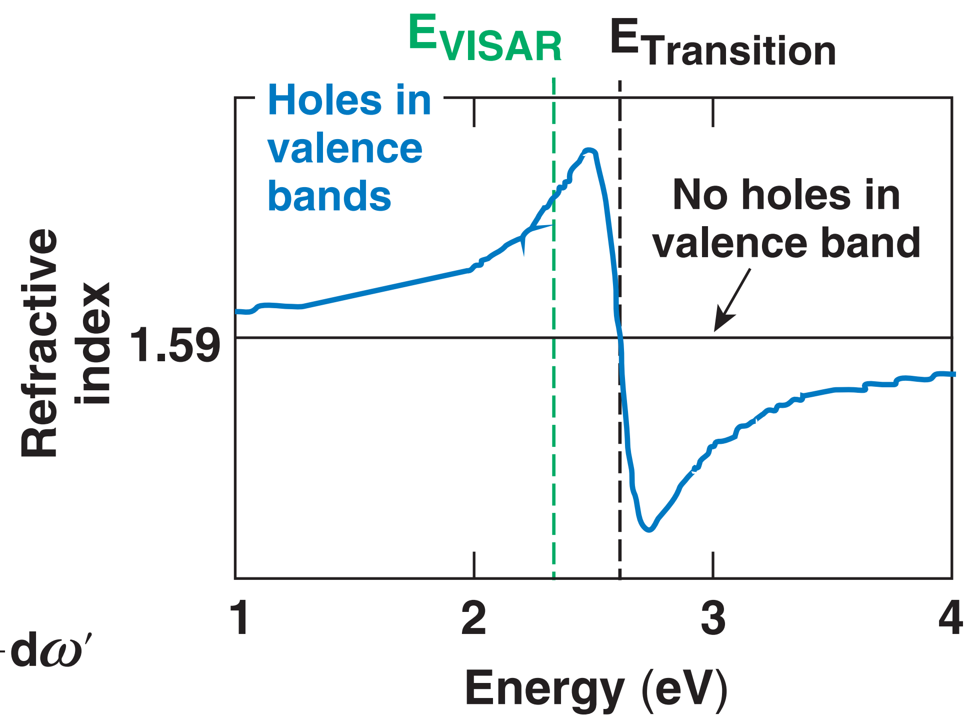
Ionization: $\omega_p \uparrow$

$dn/dt < 0 \rightarrow$ blue shift




$$n \simeq 1 + \frac{2P}{\pi} \int_0^\infty \frac{\omega' \alpha(\omega')}{\omega'^2 - \omega^2} d\omega'$$

> 2.33 eV




dn/dt > 0

E14184

†T. R. Boehly C12.005

Summary/Conclusions

# Preheating leads to a strong absorption and frequency shift of an optical-probe laser

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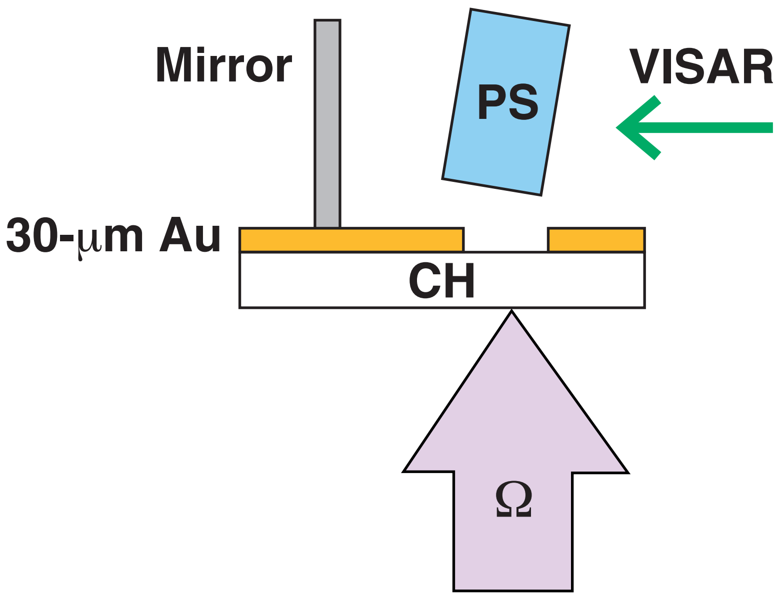
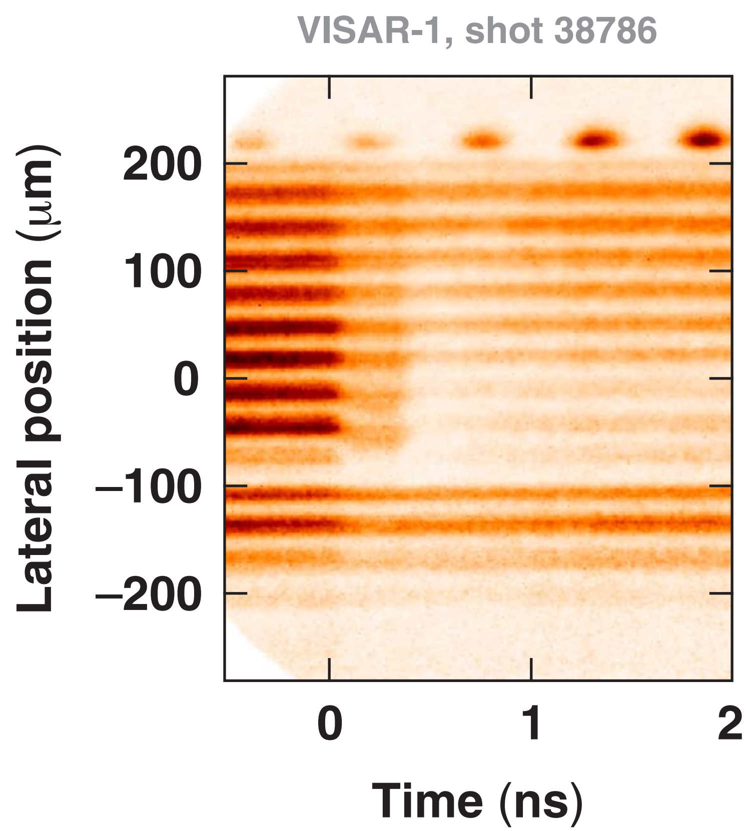
- X-ray preheating can compromise shock-timing (VISAR) measurements at high laser intensities.
- Preheat experiments using 100-ps laser pulses and planar CH targets revealed a preheat precursor of up to ~4 eV at $5 \times 10^{14}$ W/cm$^2$.
- The expansion of an aluminum layer because of preheat is inferred from a Doppler blue-shifted probe-laser wavelength.
- Preheated polystyrene leads to a strong absorption and a temporally increasing refractive index.

# A novel experiment studies preheating in polystyrene by preventing mirror heating

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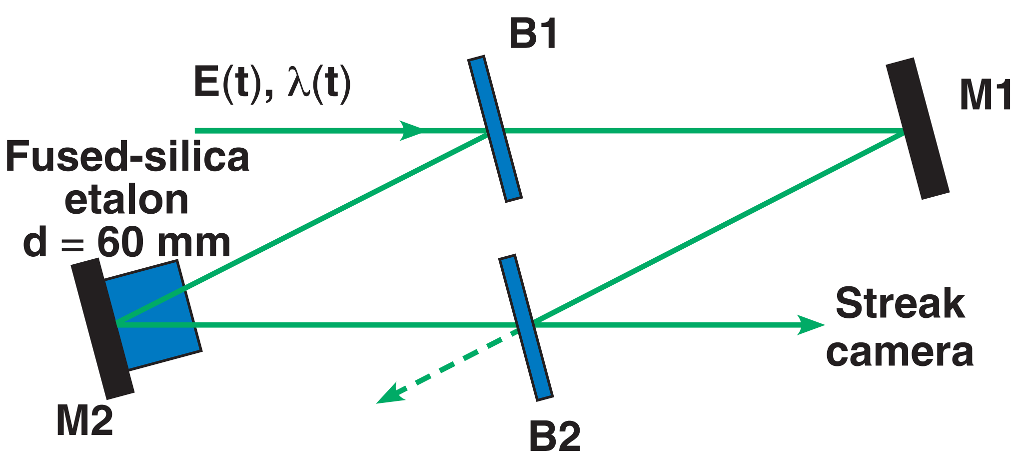
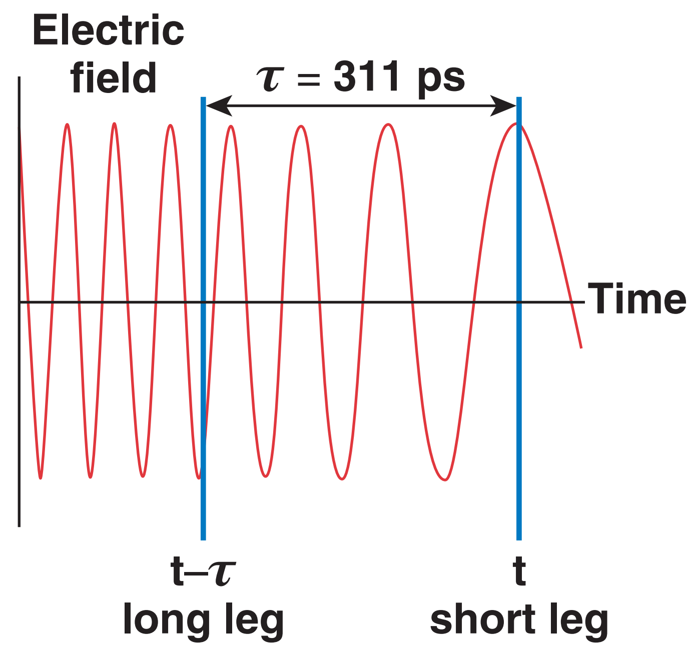
# The wavelength and amplitude variation during the VISAR etalon delay time is taken into account




**Phase change**

$$\Delta\Phi(t) = c\left[\int_0^t k(t')\,dt' - \int_0^{t-\tau} k(t')\,dt'\right] = 2\pi c \int_{t-\tau}^{t} \frac{1}{\lambda(t')}\,dt'$$

# A temporally increasing optical path length is inferred for polystyrene from a red-shifted probe wavelength

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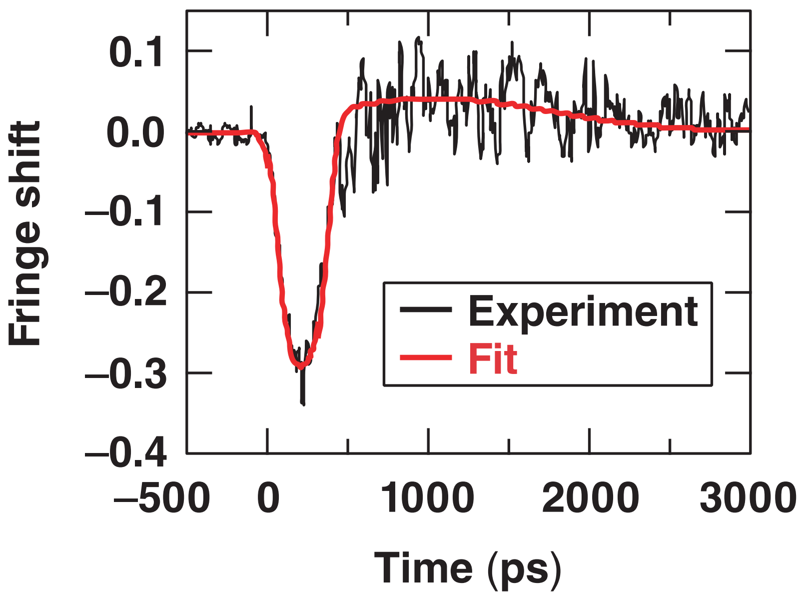



**Probe beam wavelength**

$$\lambda(t) = \lambda_0\left[1 - \frac{2}{c}\frac{\partial}{\partial t}(\eta L)\right]^{-1}$$

**Red shift**

$$\lambda(t) > \lambda_0$$

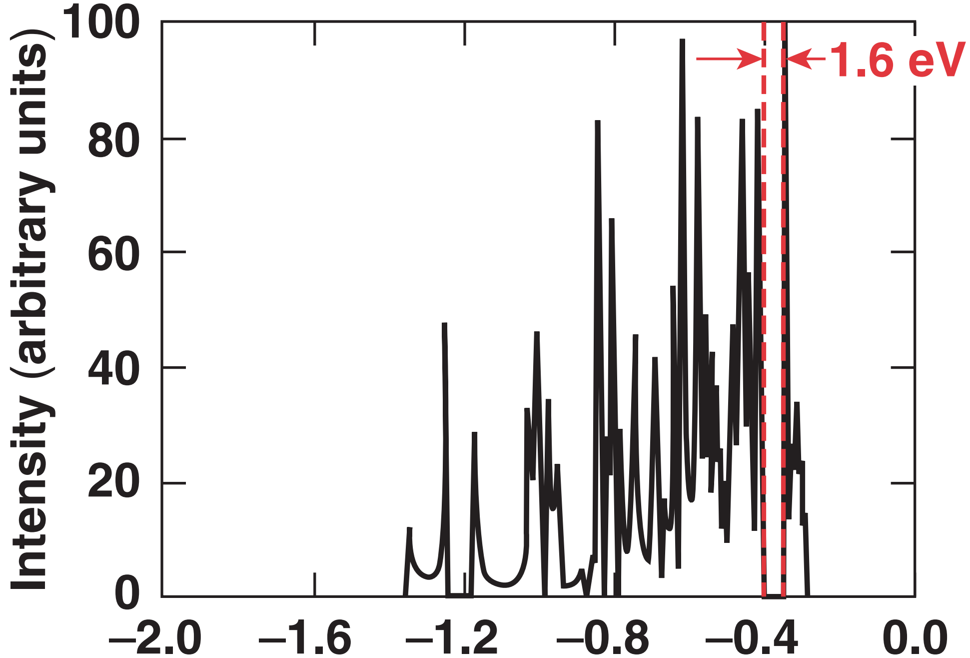
**The corresponding fringe shift is in negative direction**

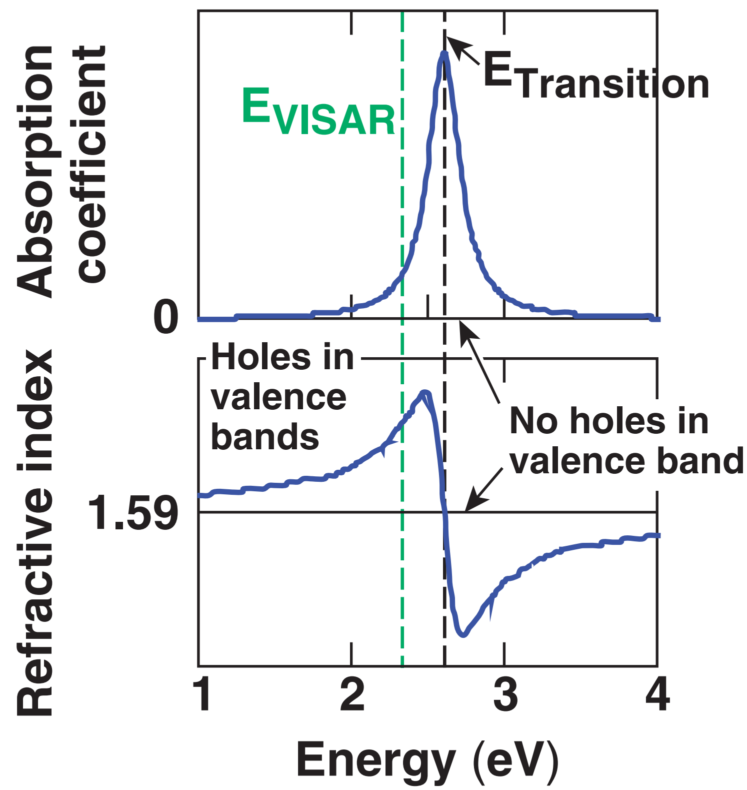
$$\Delta f(t) = c\left[\int_{t-\tau}^{t} \frac{1}{\lambda(t')}dt' - \frac{\tau}{\lambda_0}\right] = -\frac{2}{\lambda_0}\left[\eta(t)L(t) - \eta(t-\tau)L(t-\tau)\right]$$

E13841

# X-ray radiation might open optical transitions in the valence band

*VEH density of valence states for a stereo-regular polystyrene chain with a $(TG)_3$ conformation




The increase in the refractive index is proportional to the oscillator density.

E14084

*J. L. Breads and G. B. Street, J. Chem. Phys. 82, 3284 (1985).