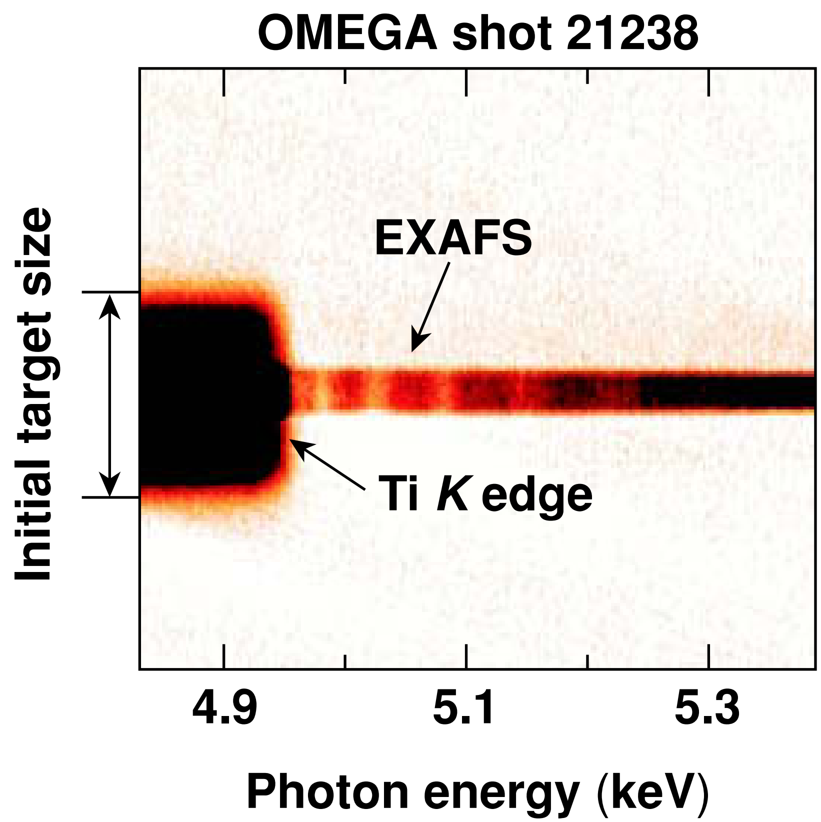
EXAFS Detection of Laser Shock Heating



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Summary

EXAFS detection of laser shock heating in metals is being studied

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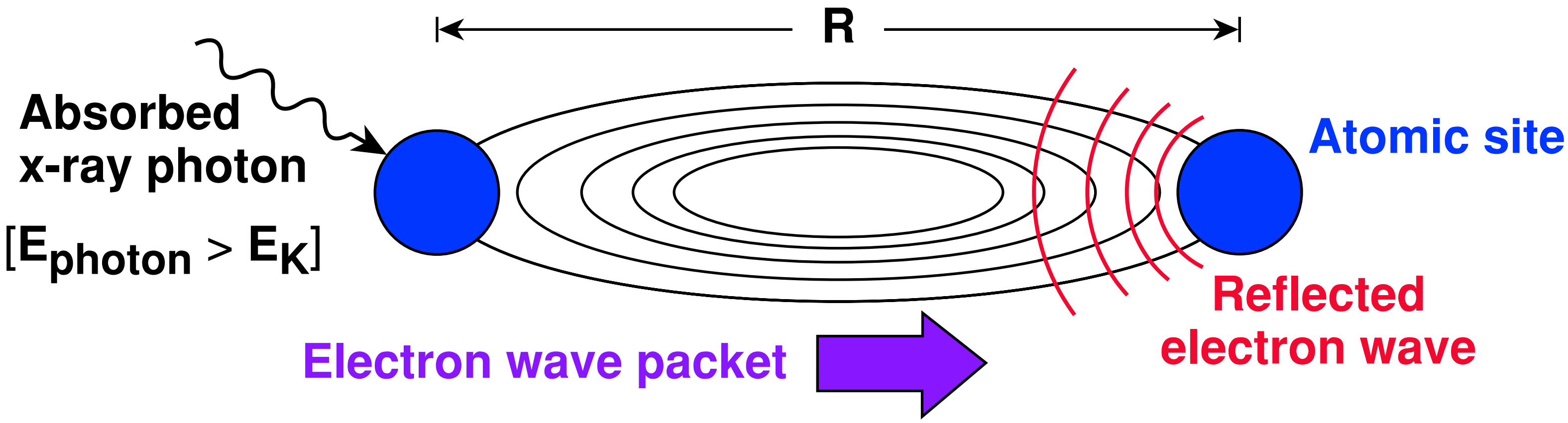
- Extended x-ray absorption fine structure (EXAFS) will be used to characterize metals shocked to ~Mbar pressures.
- High-contrast modulations for an undriven Ti-foil absorber were obtained using a laser-imploded spherical target as a backlighter.
- EXAFS modulations were studied as a function of the foil heating by radiation from the backlighter.
- By using an empirical model to describe the shock-compressed foil, we have shown that compression extends the temperature region where appreciable EXAFS modulations can be observed.

EXAFS is modulations in x-ray absorption due to interference of the ejected electron wave function with reflections from neighboring atoms



$$\hbar^2 k_{electron}^2 / 2m = E_{ph} - E_K$$

- If the two electron waves are in phase: maximum absorption
- If the two electron waves are out of phase: minimum absorption
- Phase is $k_{electron}R$.
- Modulation frequency depends on R–hence, on density.
- For higher temperatures, vibrations reduce coherence, leading to less modulation.

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EXAFS model shows the dependence of modulations in the x-ray absorption coefficient on density and temperature

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- **Model for modulations in reduced x-ray absorption coefficient above the *K* edge:**

$$\chi(k) = \Sigma_j N_j F_j(k) \exp\left[-2\sigma^2 k^2 - 2R_j/\lambda(k)\right] \sin\left[2kR_j + \phi_j(k)\right]/kR_j^2$$

Damping due to lattice vibrations

$\sigma^2 = f(t/\theta_D)$

Electron mean free path

Modulations due to neighboring atoms

- **For shock heating, compression increases $\theta_D \sim h\nu_m/k_B$ (ν_m, the maximum lattice frequency $\sim \rho^{1/3}$).**

$$\hbar^2 k^2/2m = E_{ph} - E_K$$

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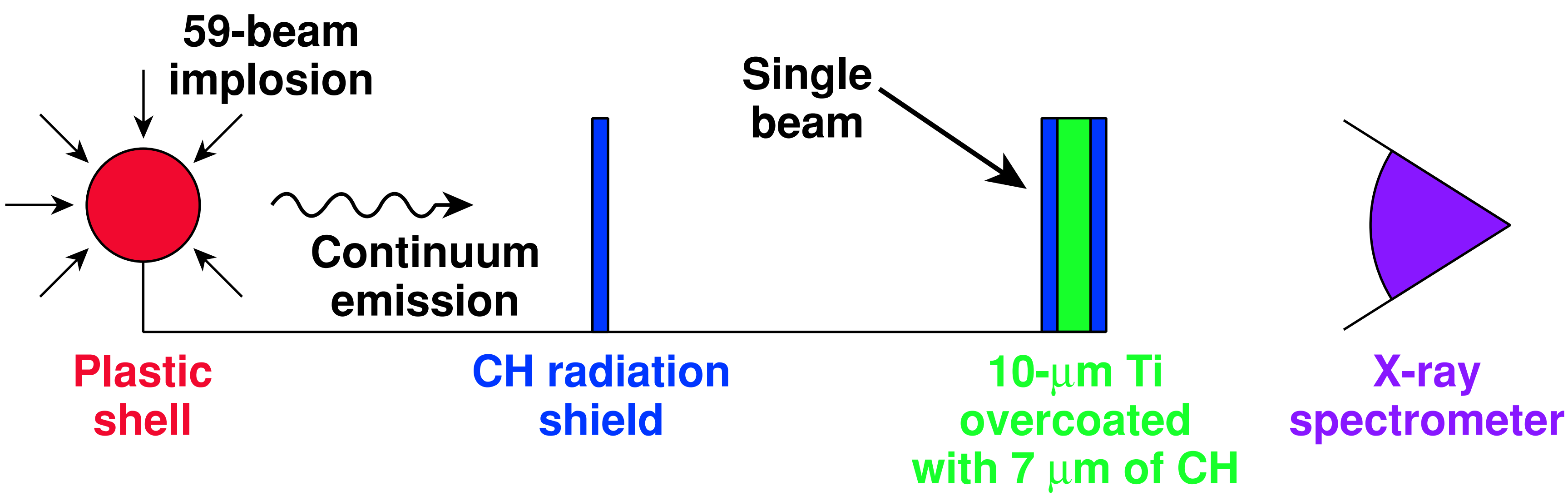
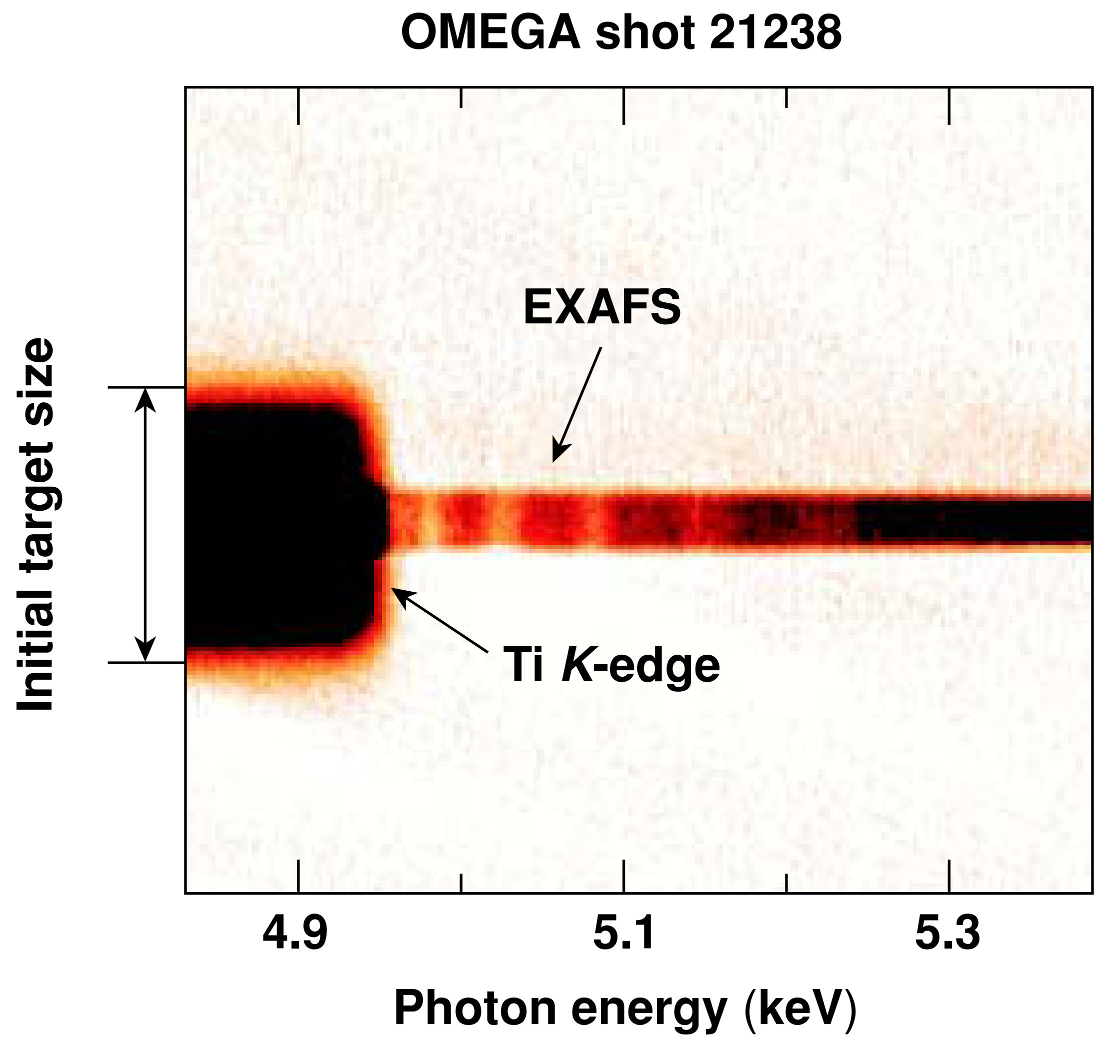
EXAFS is observed in thick metal foils backlit by a spherical target implosion



- The foil is heated by
  - a shock wave from the single beam and/or
  - radiation from continuum emission.

CID-recorded EXAFS spectrum of Ti foil backlit by imploded target



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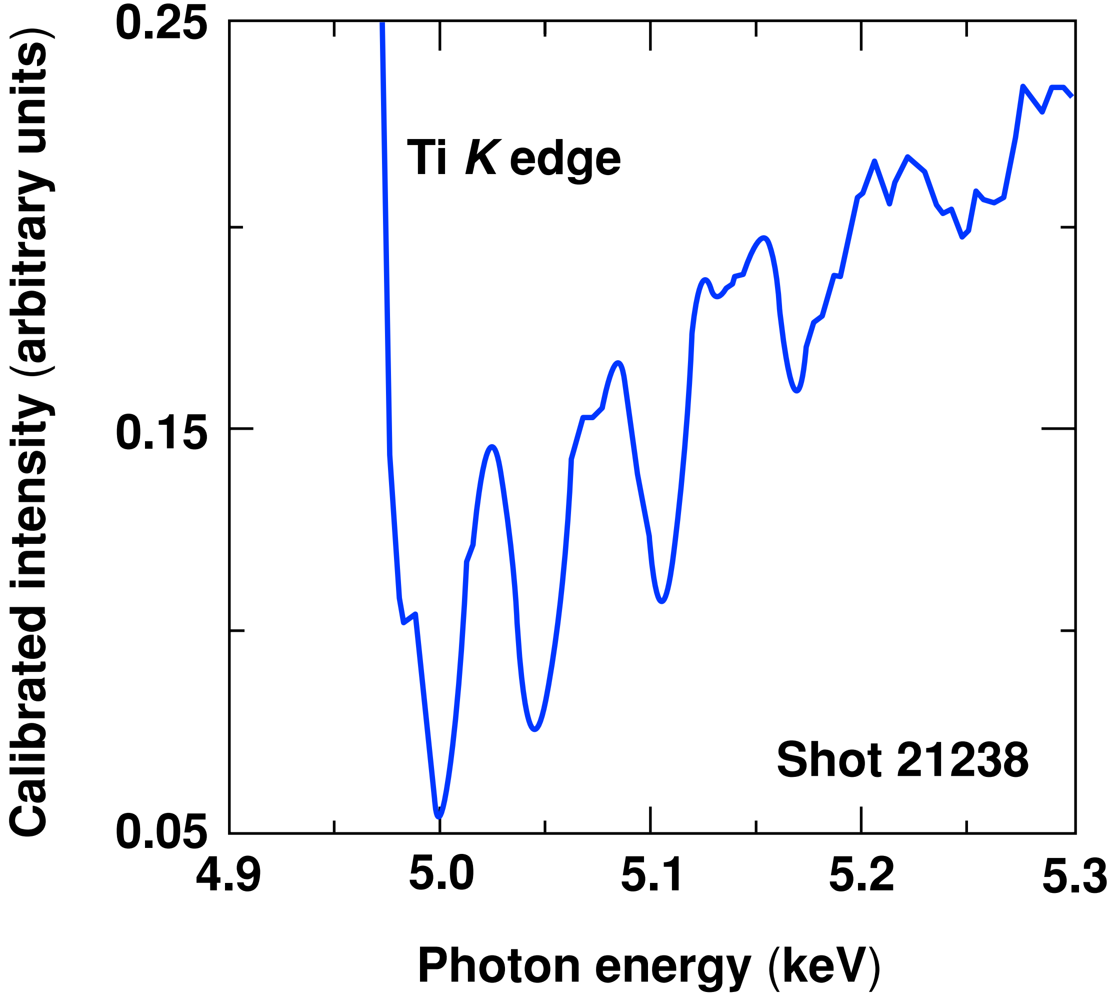
The calibrated EXAFS spectrum shows significant modulation



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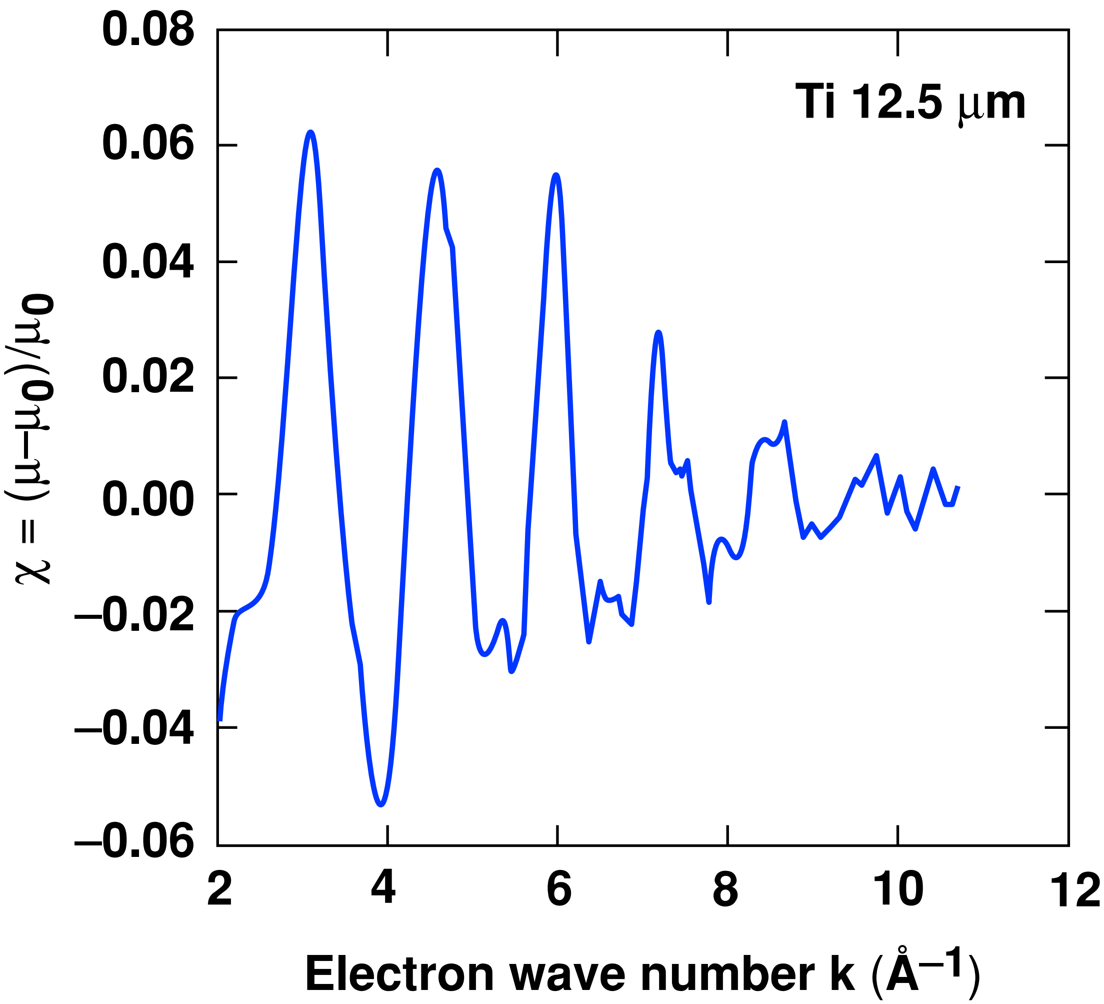
Reduced EXAFS spectrum is used for comparison to model; k is related to E through $\hbar^2k^2/2m = E - E_K$; $E_K = E$ (K edge)



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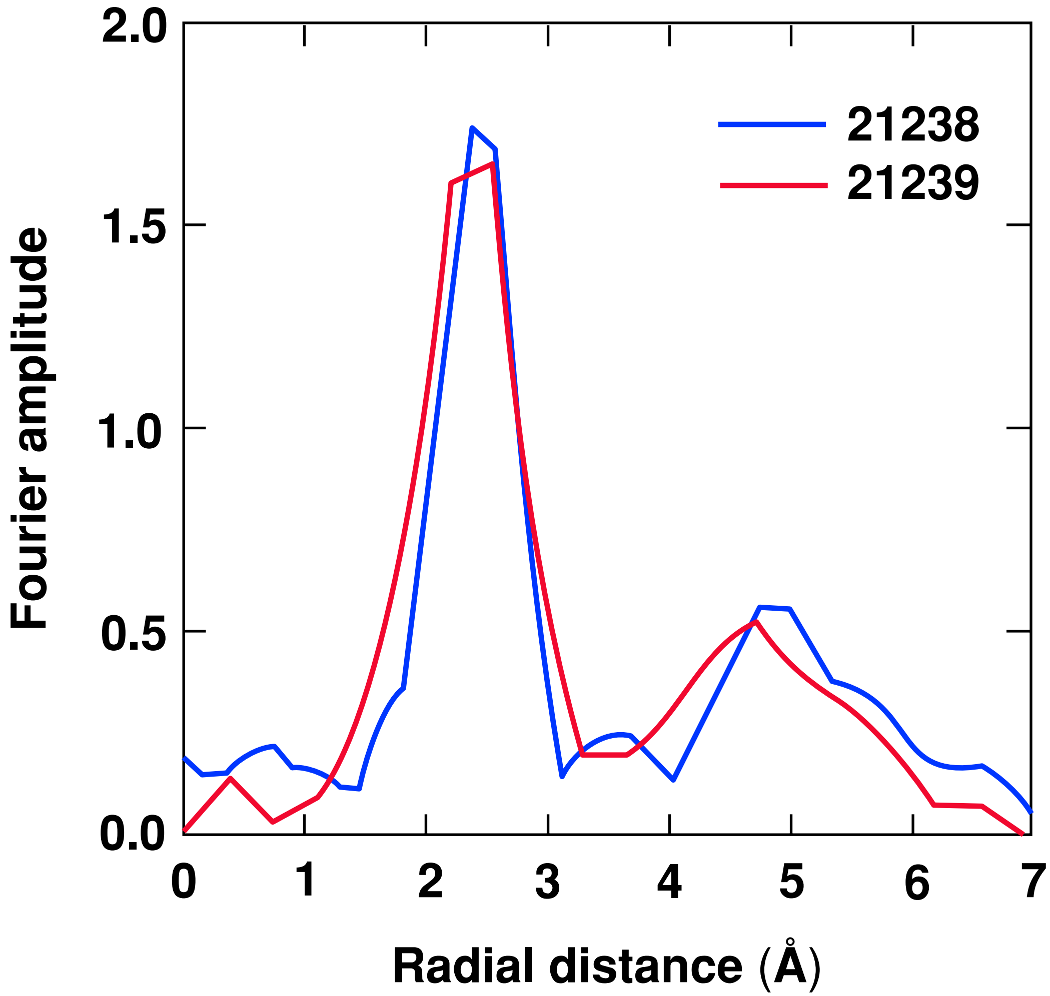
Charge distribution in space is obtained by FFT of Ti EXAFS spectrum



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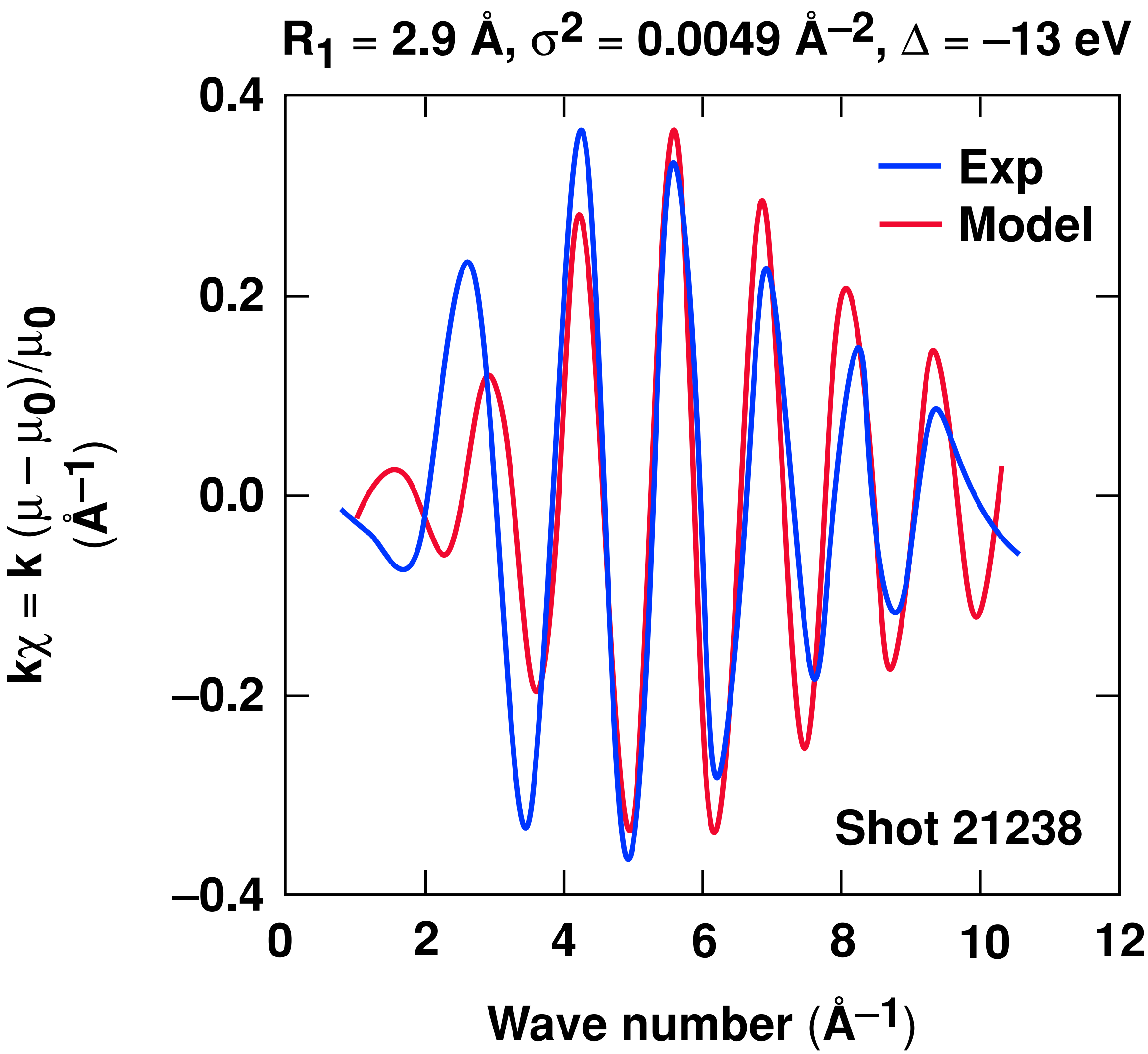
Fitting EXAFS model to experiment (after Fourier filtering) yields R (density) and σ^2 (temperature)



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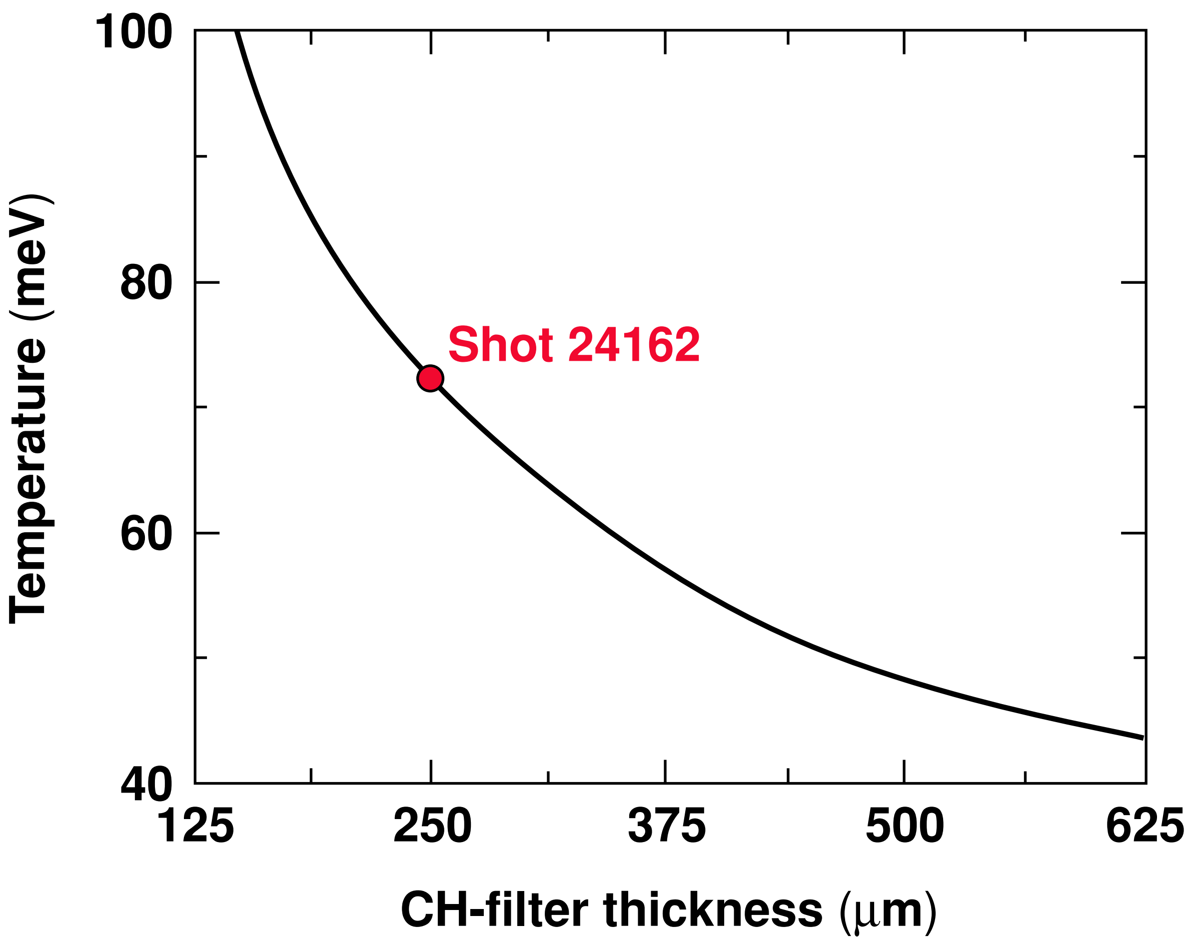
Calculated radiation-heating temperature of Ti foil versus CH heat-shield thickness; predicted T for shot 24162 is ~ 0.07 eV



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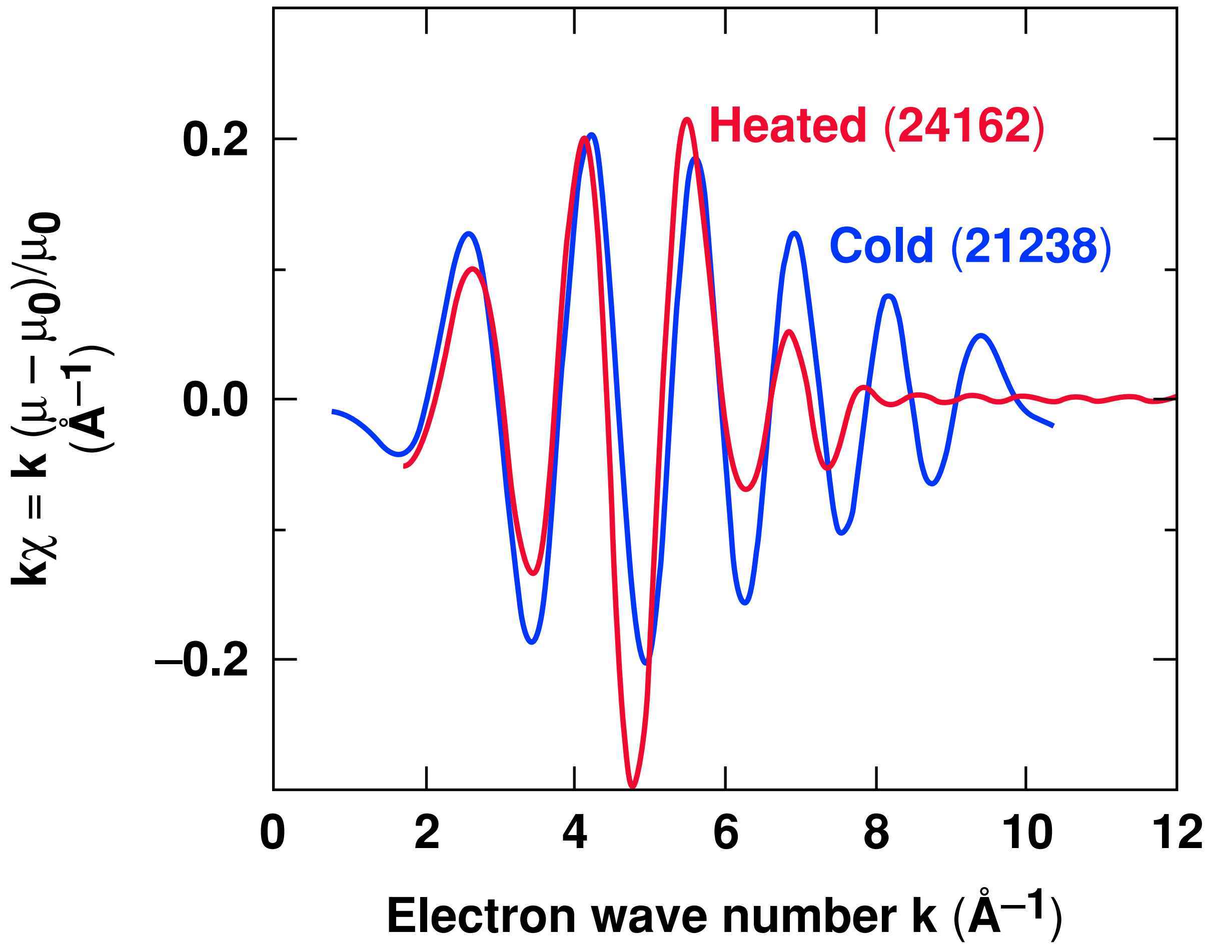
Measured EXAFS spectrum in cold and heated (~0.1 eV) Ti foil; in the heated spectrum, Ti modulations decay faster



- **EXAFS model gives T = 0.1 eV, close to 0.07 eV expected.**

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Summary/Conclusions

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- Extended x-ray absorption fine structure (EXAFS) will be used to characterize metals shocked to ~Mbar pressures.
- High-contrast modulations for an undriven Ti-foil absorber were obtained using a laser-imploded spherical target as a backlighter.
- EXAFS modulations were studied as a function of the foil heating by radiation from the backlighter.
- By using an empirical model to describe the shock-compressed foil, we have shown that compression extends the temperature region where appreciable EXAFS modulations can be observed.
- Preliminary experiments suggest EXAFS will be useful to study shock-heated materials.

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