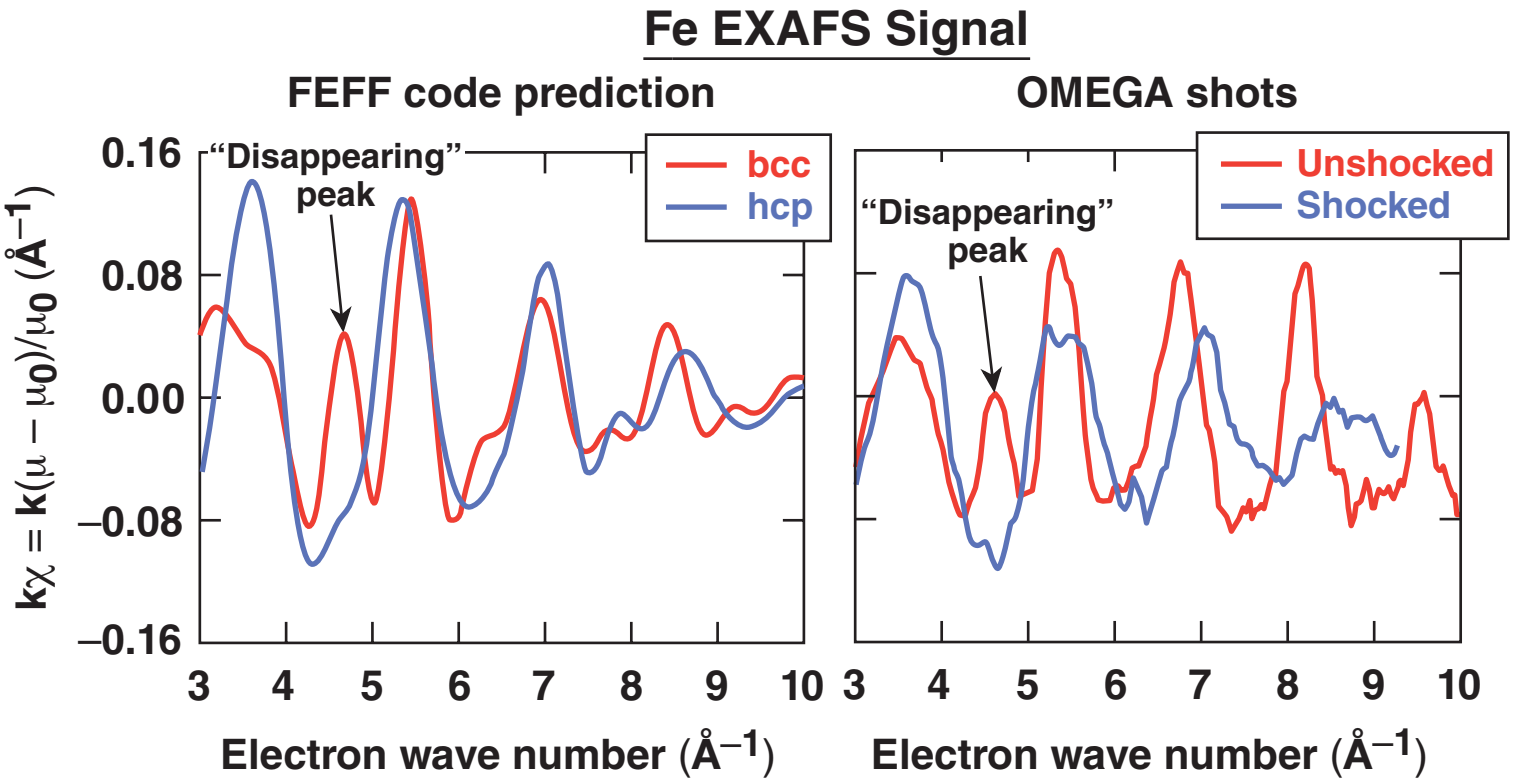
Dynamic EXAFS Probing of Laser-Driven Shock Waves and Crystal Phase Transformations



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Summary

EXAFS has been used to observe a shock-induced phase transformation in iron

UR LLE

- Previous extended x-ray absorption fine structure (EXAFS) experiments on OMEGA have shown*
  - shock-induced compression in V, and
  - shock-induced compression and phase change in Ti.
- EXAFS has been used to observe a shock-induced phase change in Fe at ~10 GPa (100 Kbar) on a nanosecond time scale.
  - The measured EXAFS signal of unshocked Fe is in agreement with synchroton measurements.
  - A clear change in the EXAFS spectrum shows unambiguous evidence for a phase change in Fe from the bcc (α) to hcp (ε) states.

*B. Yaakobi *et al.*, Phys. Plasmas 11, 2688 (2004).

Collaborators

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EXAFS

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

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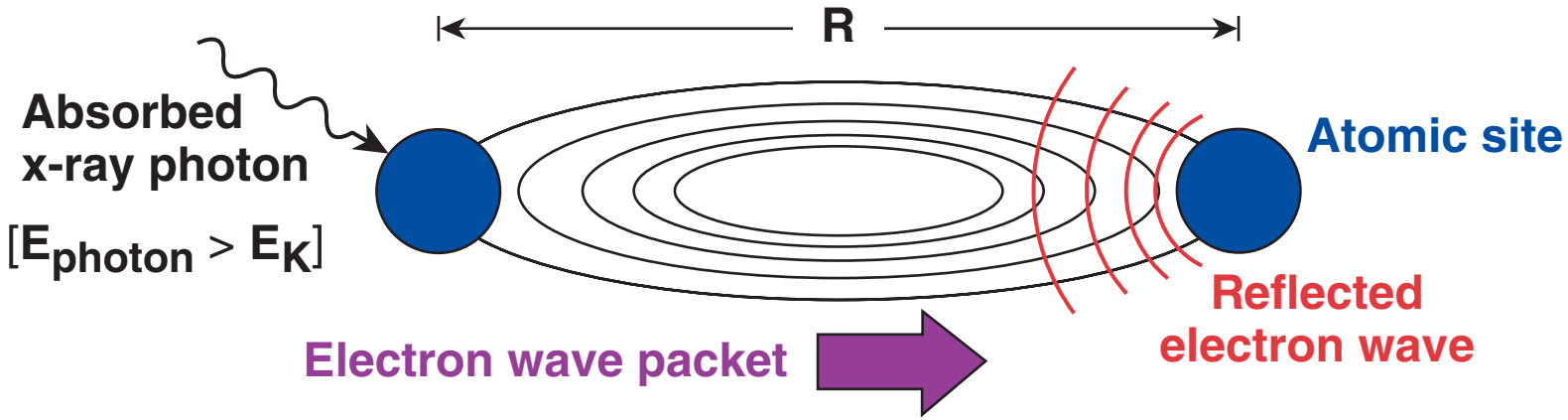
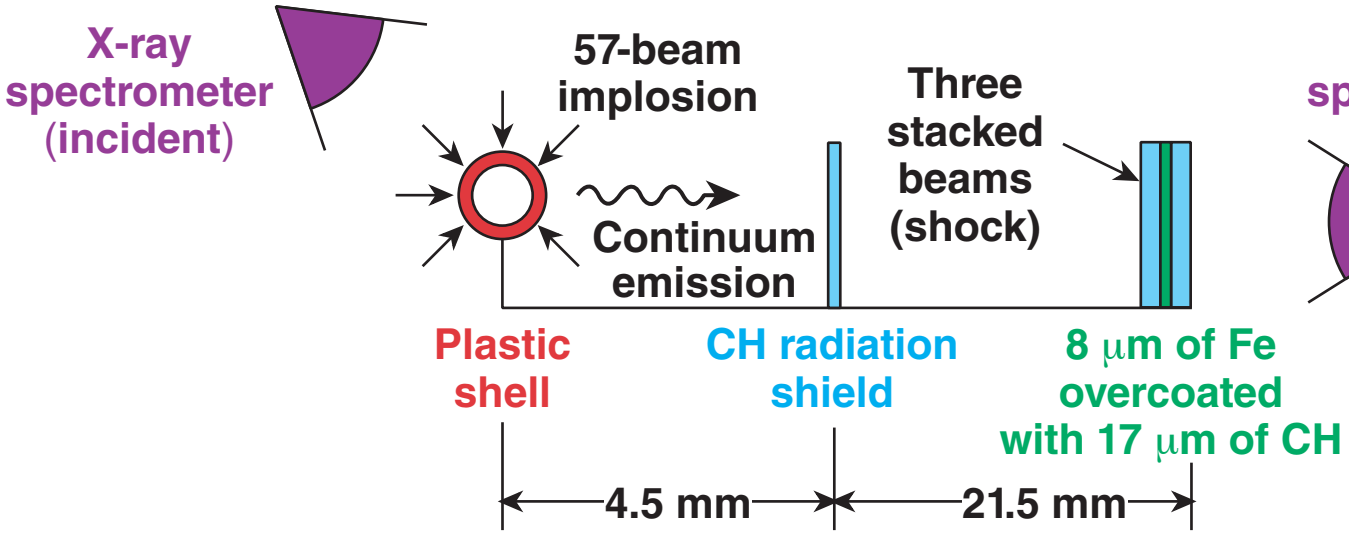


$$\hbar^2 k^2_{electron} / 2m = E_{ph} - E_K$$

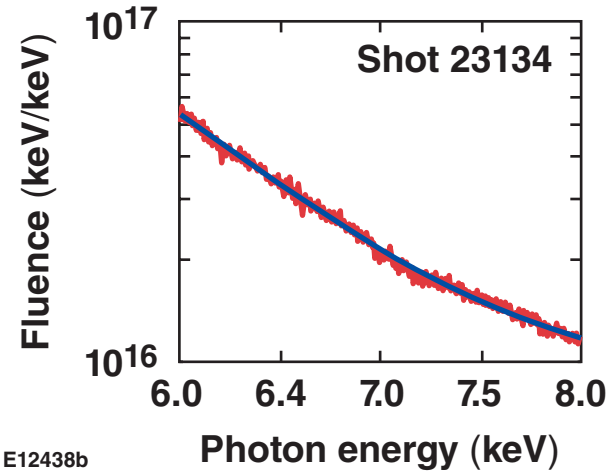
- If the two electron waves are
  - in phase: maximum absorption
  - out of phase: minimum absorption
- Phase is $k_{electron} R$.
- Modulation frequency depends on R and, hence, on density.
- For higher temperatures, vibrations reduce coherence, leading to less modulation.

E11281a

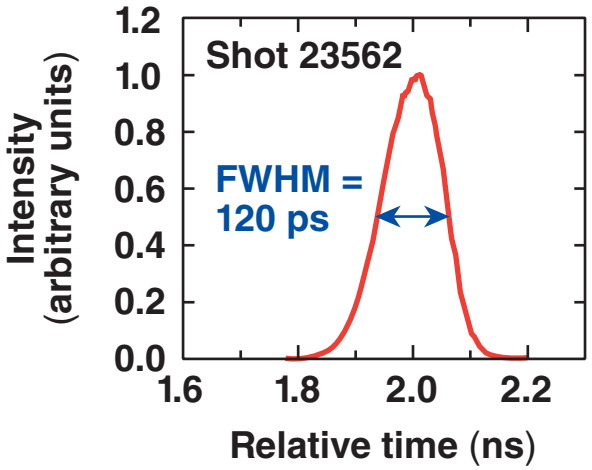
EXAFS is observed on OMEGA in thick metal foils backlit by a spherical target implosion



Featureless spectrum



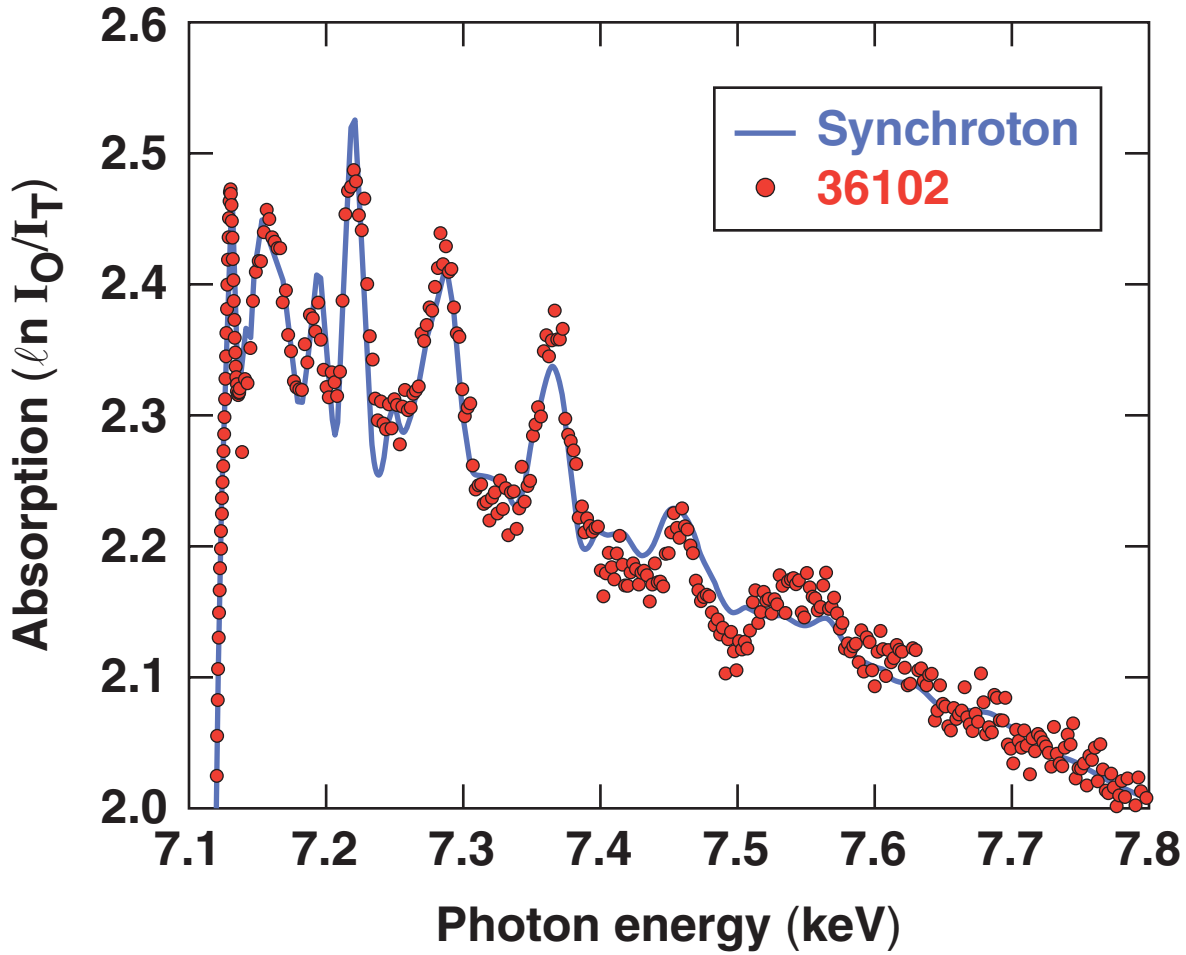
18.5-μm-thick empty CH shell, 23 kJ



The direct-drive implosion provides an extremely bright and smooth x-ray source.

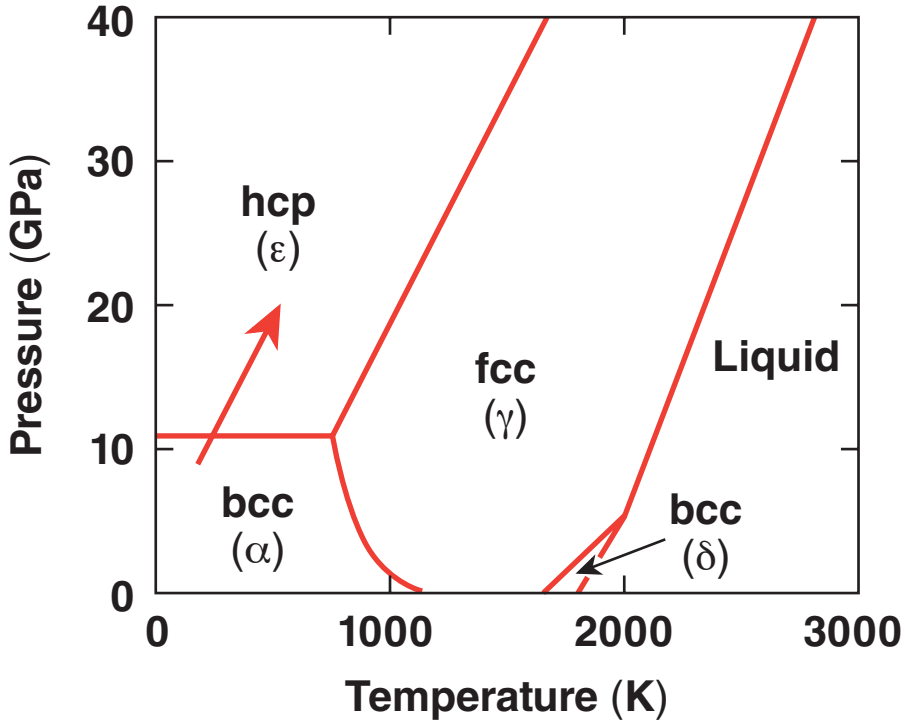
E12438b

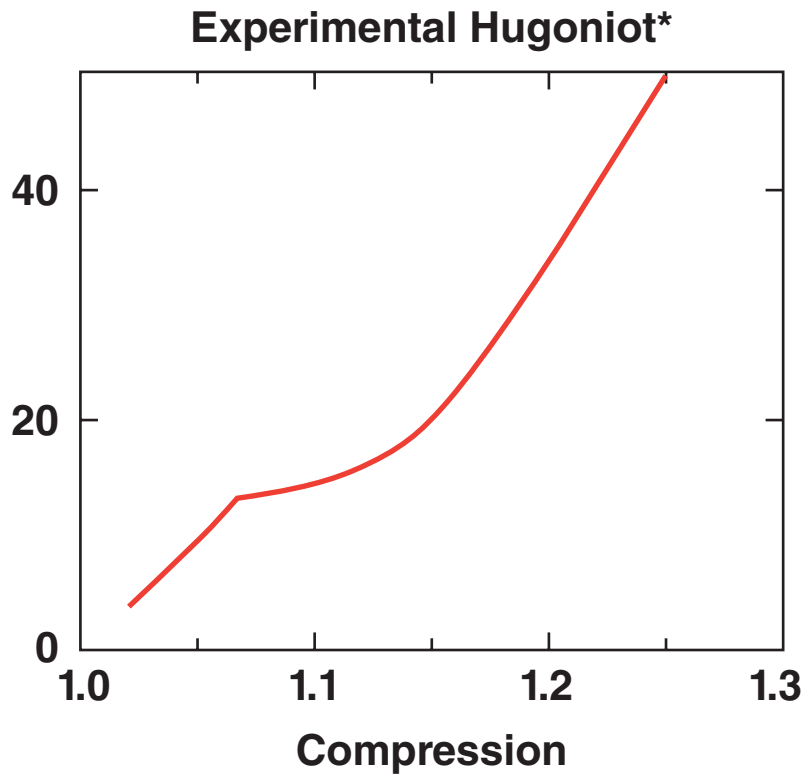
The unshocked EXAFS spectrum from OMEGA is in good agreement with the standard Fe EXAFS spectrum



E13297a

A shock induced phase change in Fe from bcc to hcp occurs at ~10 GPa (~100 Kbar)

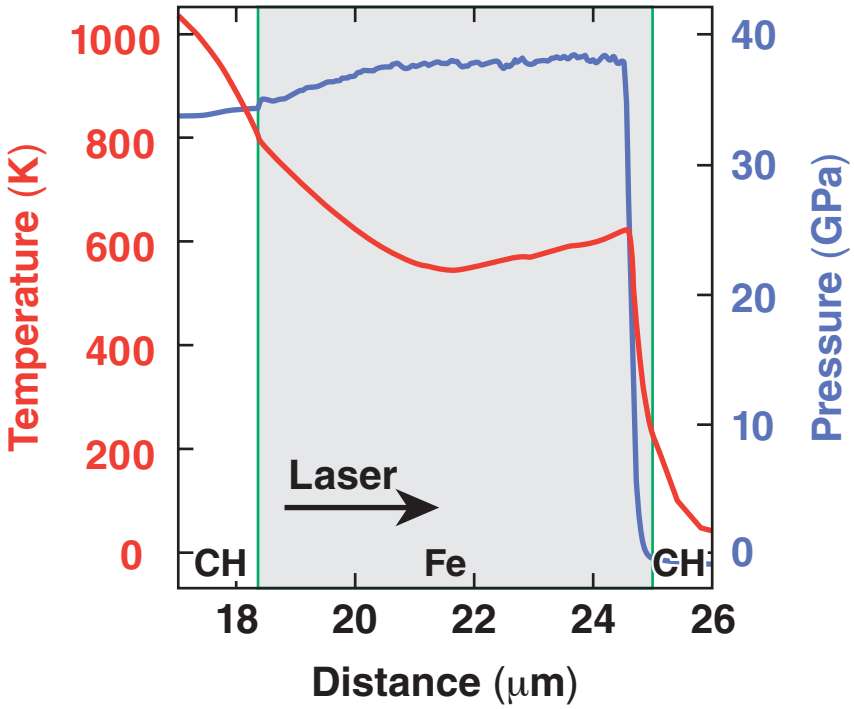


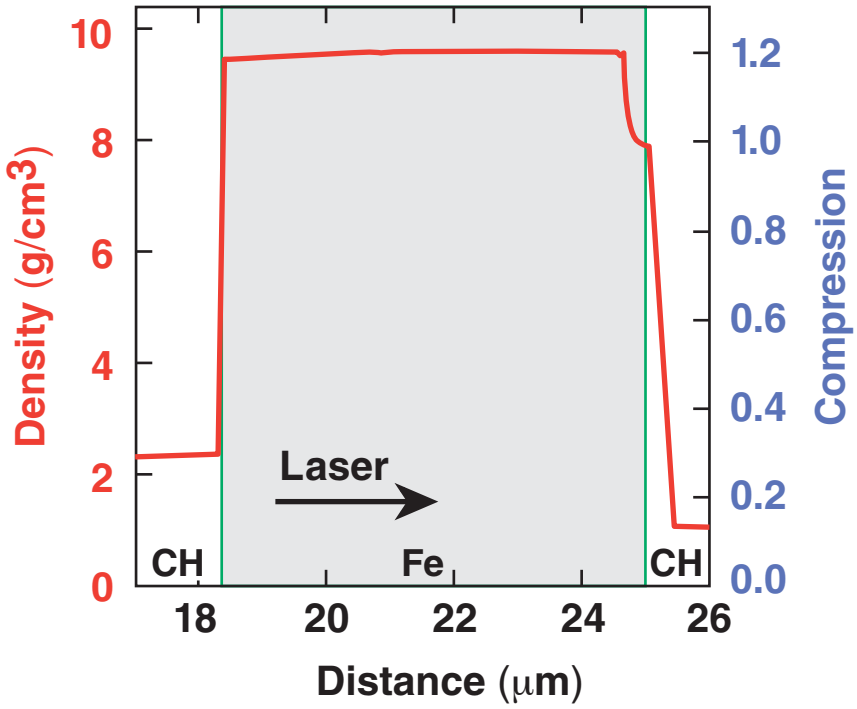


*Bancroft *et al.* (1956); Barker *et al.* (1974)

E13292a

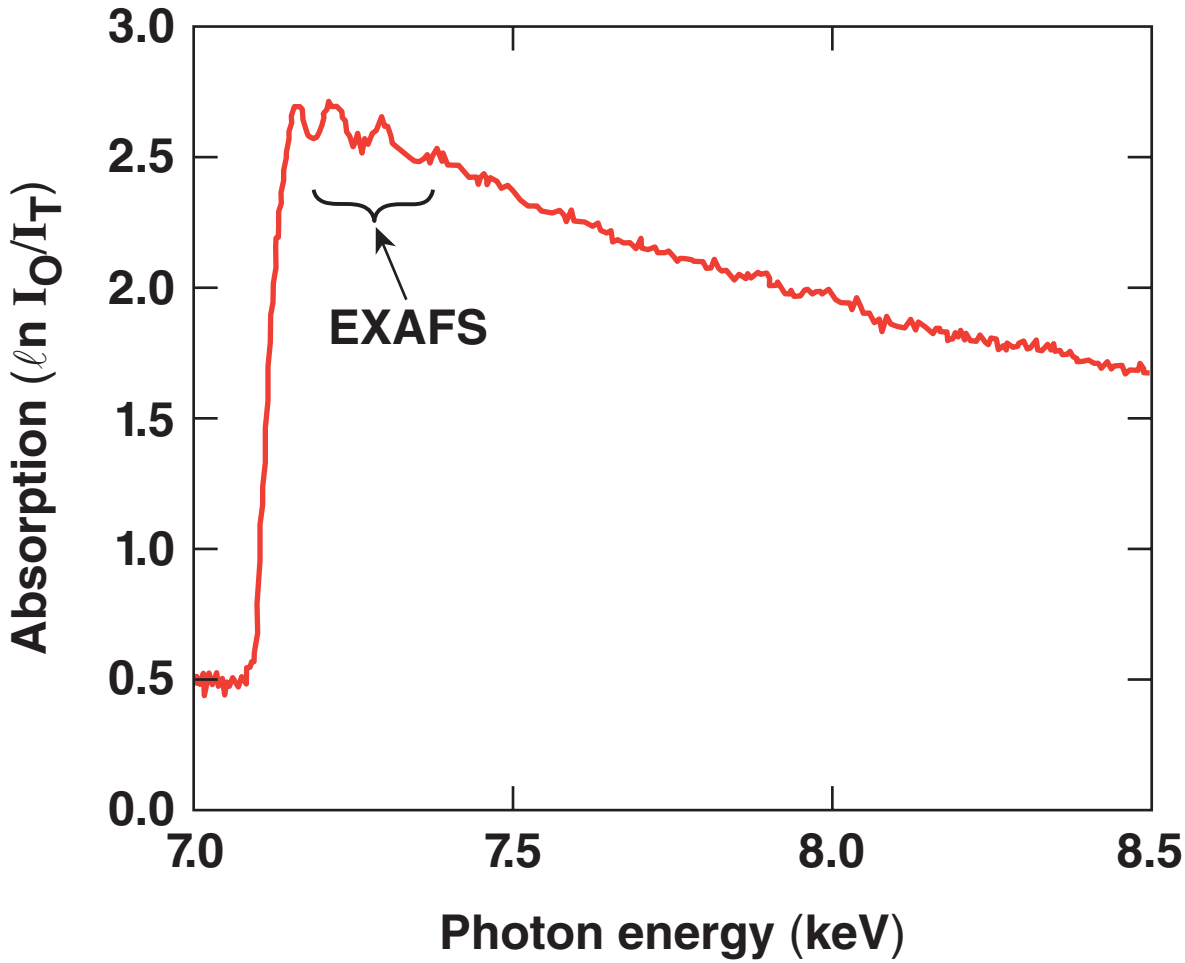
LASNEX simulation of shocked iron at 0.5 TW/cm^2 shows uniform compression





E13345a

The absorption through shocked iron shows EXAFS modulations (shot 37356)



E13296

EXAFS spectra show evidence for compression and crystal-phase transformation in shocked iron on OMEGA

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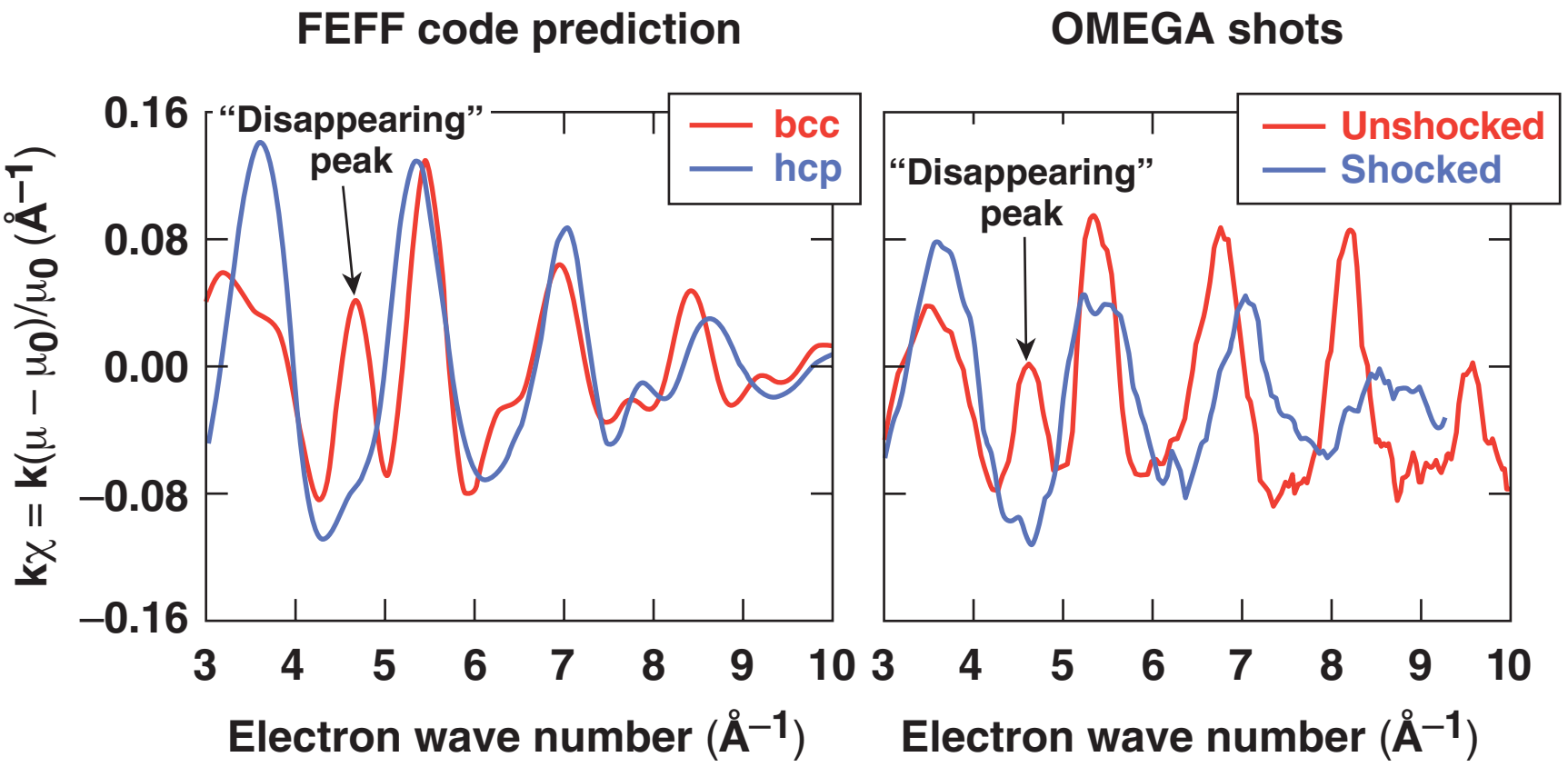

"Missing" peak indicates phase transformation.

Change in frequency indicates compression.

E13301b

Summary/Conclusions

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