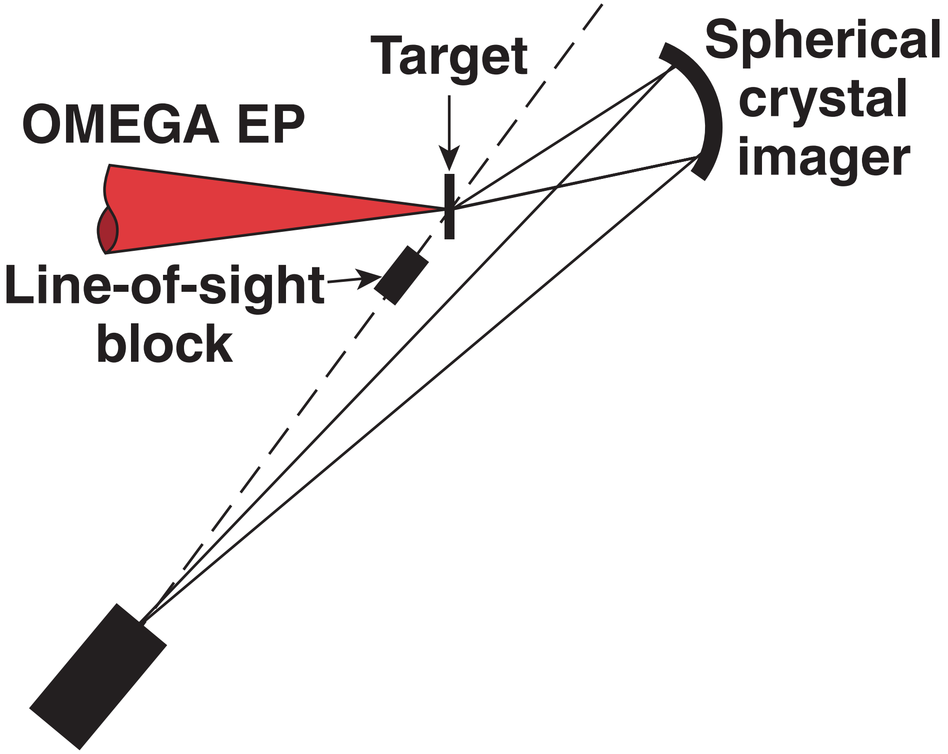
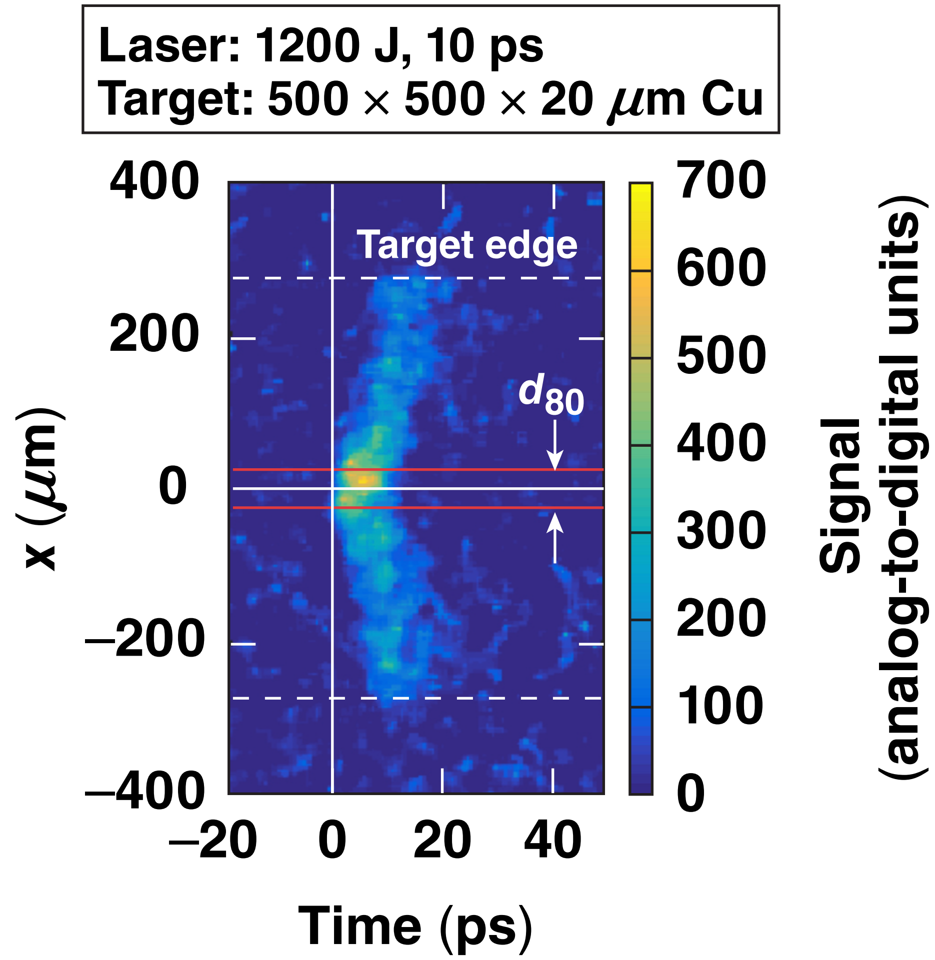
Supersonic Propagation of a K-Shell Ionization Front in Metal Targets





P. M. Nilson
University of Rochester
Laboratory for Laser Energetics

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Summary

Hot-electron–driven ionization fronts were measured in high-intensity, laser-irradiated metal targets

UR LLE

- A monochromatic, streaked x-ray crystal imager has been developed for the OMEGA EP laser to study collisional ionization-front dynamics in solid-density metals

- Spatial, spectral, and temporal resolution is obtained by coupling a spherically bent crystal imager with a 2-ps-resolution x-ray streak camera

- Implicit-hybrid particle-in-cell (PIC) and collisional-radiative code calculations are used to model the hot-electron transport, target heating, and front dynamics

The predicted front and target-heating dynamics are consistent with experimental observations.

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Collaborators

C. Stoeckl, P. A. Jaanimagi,* C. Mileham, W. Theobald,† J. R. Davies,†
J. F. Myatt, A. A. Solodov,† D. H. Froula, and R. Betti,†

University of Rochester
Laboratory for Laser Energetics
†also Fusion Science Center

G. Fiksel

University of Michigan

D. D. Meyerhofer

Los Alamos National Laboratory

*Retired

Little time- and space-resolved data exists on ultrafast energy transport inside solid matter

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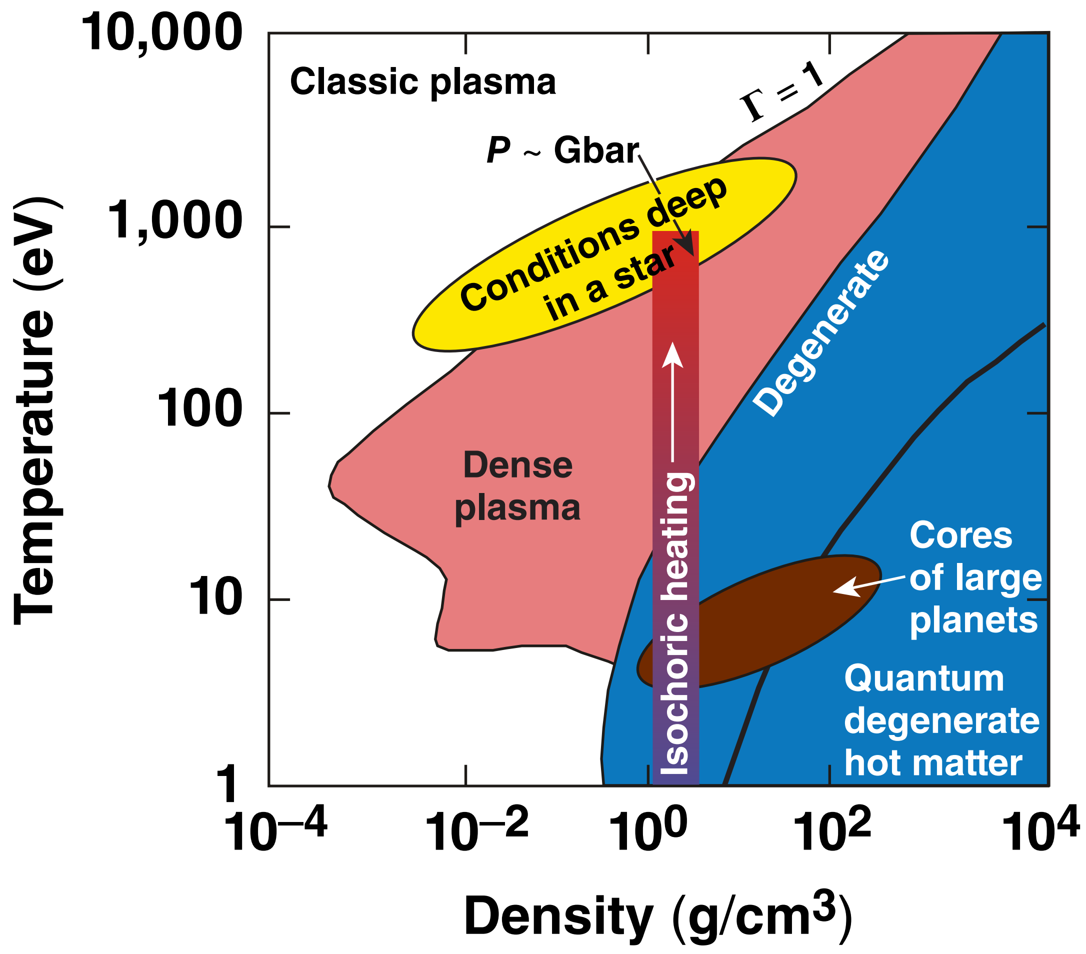
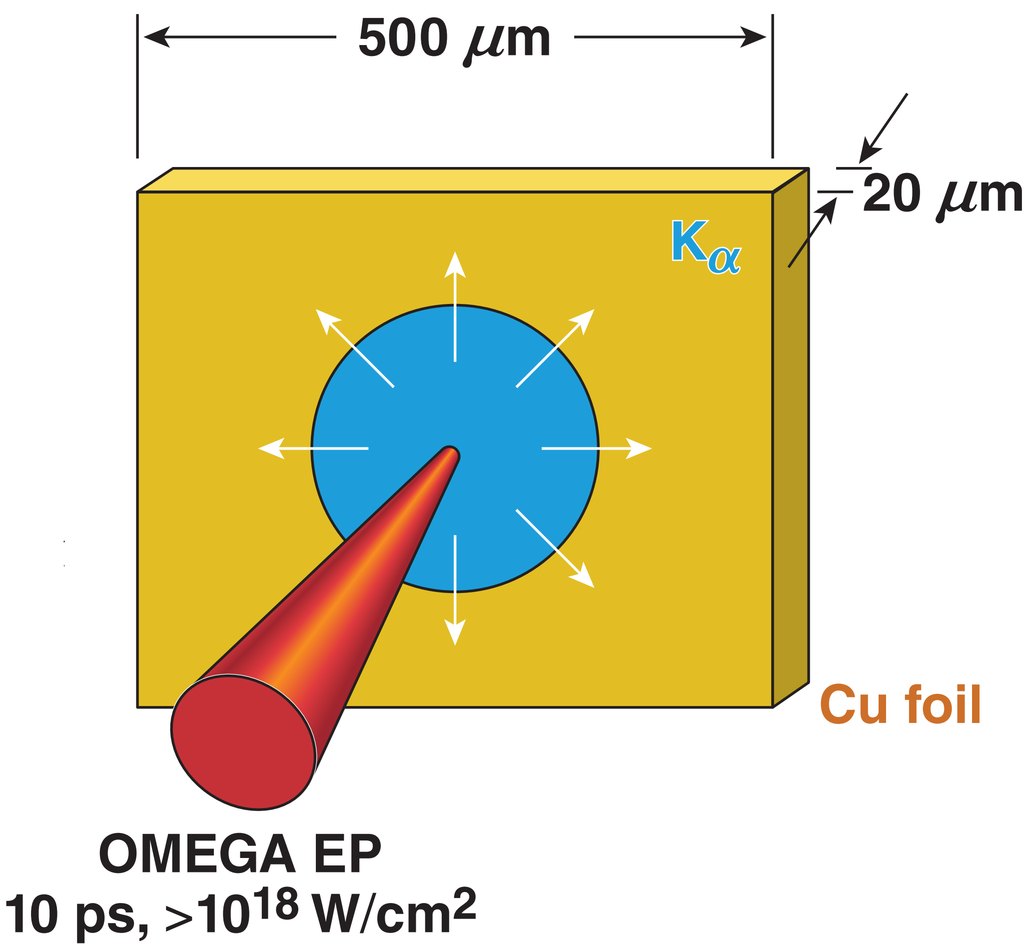
- Warm-dense-matter (WDM) systems start as a solid and end as a plasma
- WDM is found in stellar interiors, cores of large planets, and inertial confinement fusion (ICF) implosions[1,2]
- Significant uncertainties exist in WDM equation of state[3] and opacity[4]

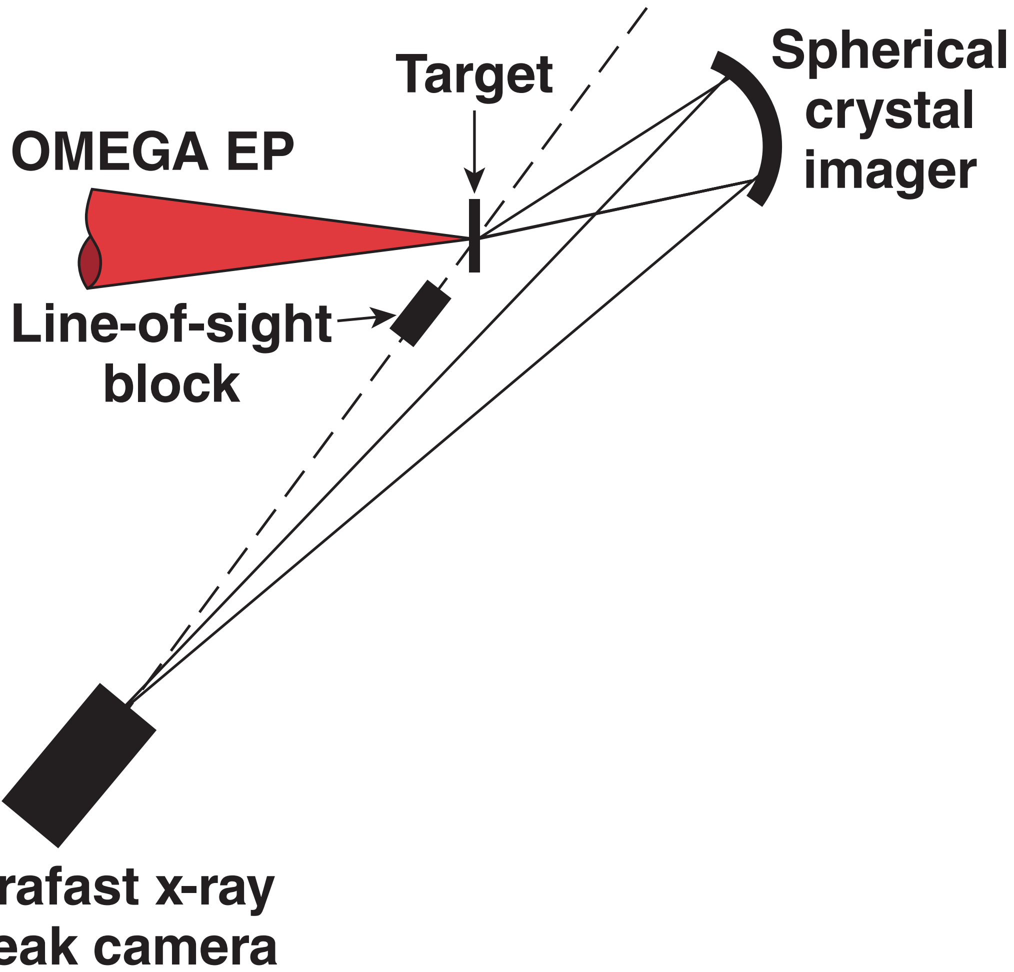


Measurements are required for model development.

[1] A Report on the SAUUL Workshop, Washington, DC (17–19 June 2002).
[2] R. W. Lee *et al.*, Lawrence Livermore National Laboratory, Livermore, CA, Report UCRL-TR-203844 (2004).
[3] M. E. Foord, D. B. Reisman, and P. T. Springer, Rev. Sci. Instrum. 75, 2586 (2004).
[4] R. A. London and J. I. Castor, High Energy Density Phys. 9, 725 (2013).

Spatial, spectral, and temporal resolution is obtained by coupling a spherical crystal imager with an ultrafast x-ray streak camera





S. A. Pikuz *et al*., Rev. Sci. Instrum. 68, 740 (1997);
J. A. Koch *et al*., Rev. Sci. Instrum. 74, 2130 (2003);
Y. Aglitskiy *et al*., Phys. Rev. Lett. 87, 265001 (2001);
R. B. Stephens *et al*., Phys. Rev. E 69, 066414 (2004).

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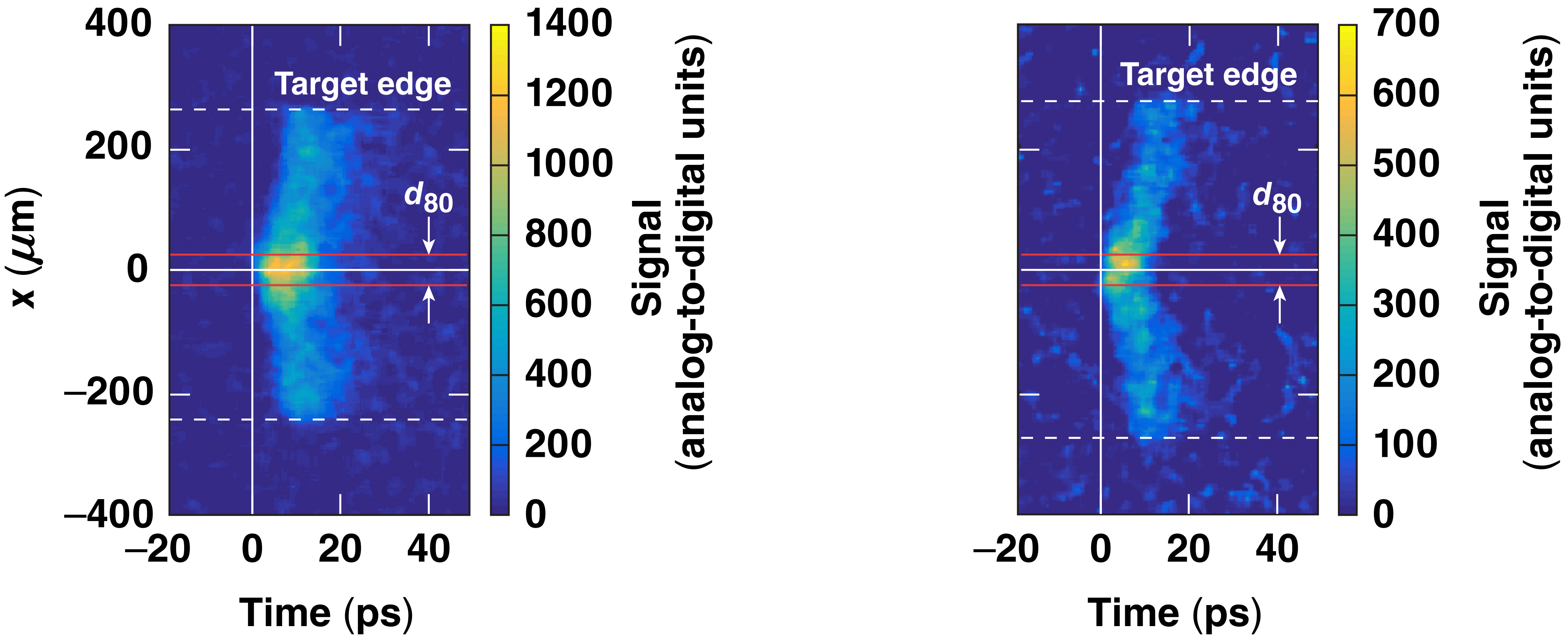
Streaked K_α imaging shows a collisional ionization front and ultrafast energy transport into the target

Laser: 250 J, 10 ps
Target: 500 × 500 × 20 μm Cu

Laser: 1200 J, 10 ps
Target: 500 × 500 × 20 μm Cu



The initial hot-electron beam diameter is comparable to the laser focal-spot size.

d_{80}: diameter containing 80% of the laser energy

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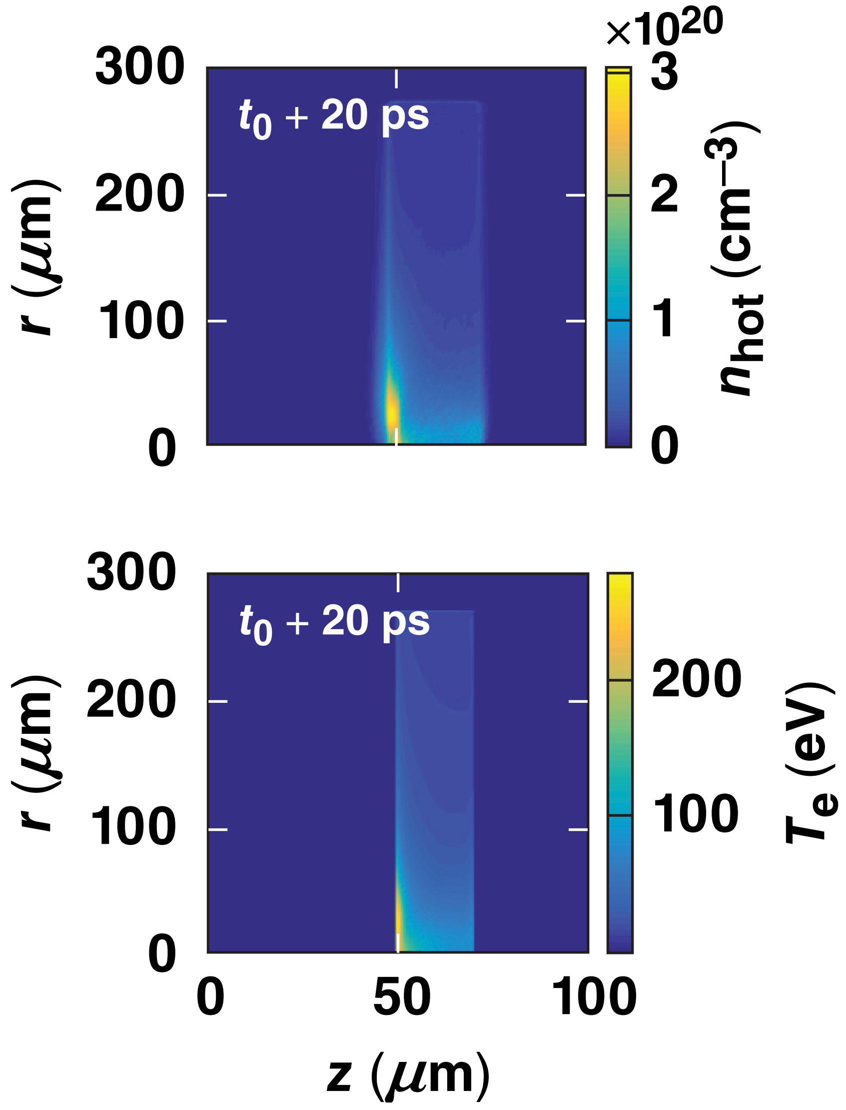
The K_α front dynamics are modeled in two parts

- Hot-electron transport, target heating, and K_α emission are calculated using the hybrid particle-in-cell code *LSP**
- The K_α signal in the aperture energy bandwidth of the crystal imaging system is corrected for
  - temperature-dependent K_α-yield suppression and spectral shifts
  - opacity effects along the diagnostic line of sight (LOS)
  - geometric effects

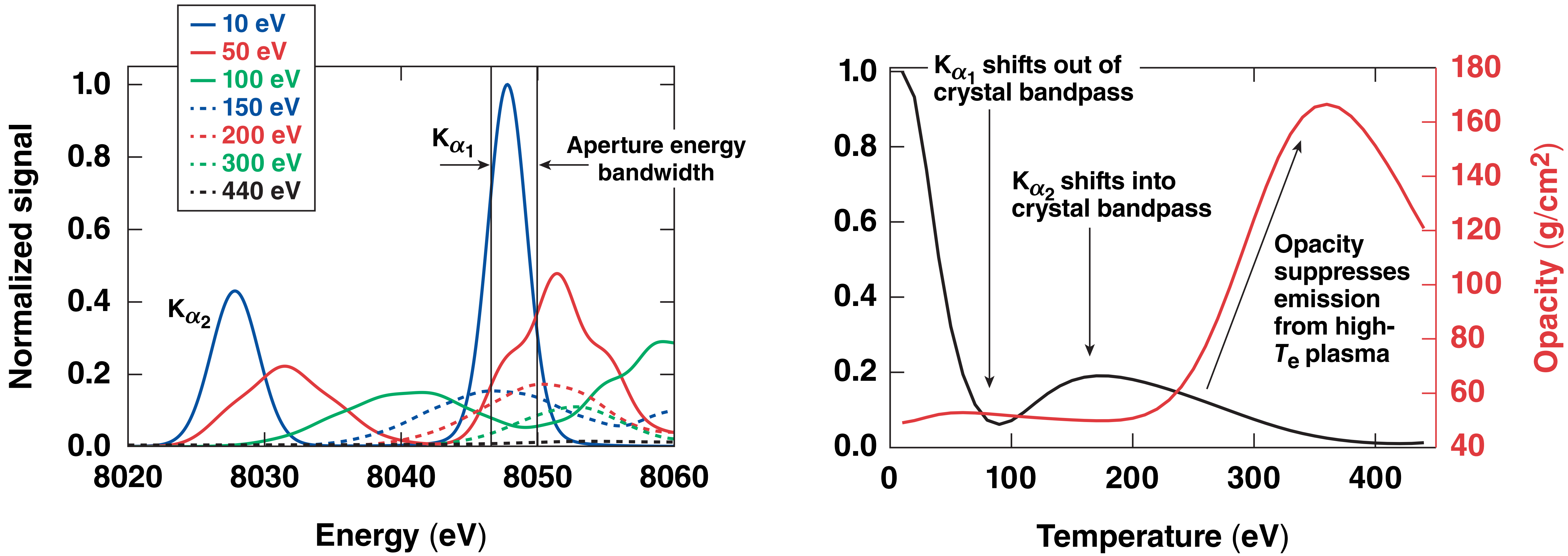
Cold K_α emission profiles calculated by *LSP* are corrected based on the local temperature at the time of emission.

Laser: 1200 J, 10 ps



*D. R. Welch *et al.*, Nucl. Instrum. Methods Phys. Res. A 464, 134 (2001).

K_α-yield suppression, spectral shifts, and opacity modify the signal in the aperture energy bandwidth



These data are used to post-process the cold K_α-emission profiles predicted by *LSP*.

PrismSPECT, Prism Computational Sciences, Inc., Madison, WI 53711.

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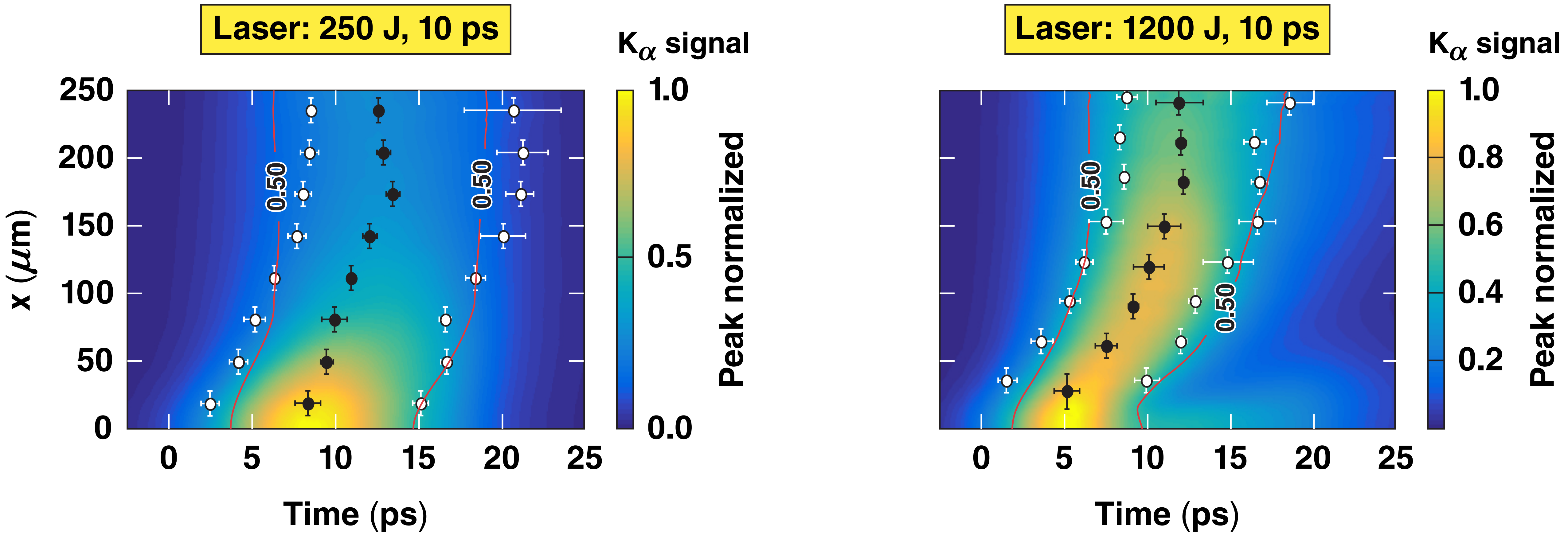
The predicted ionization front and heating dynamics show reasonable agreement with the data



Target heating suppresses K$_\alpha$ emission from the central regions of the target.

Summary/Conclusions

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