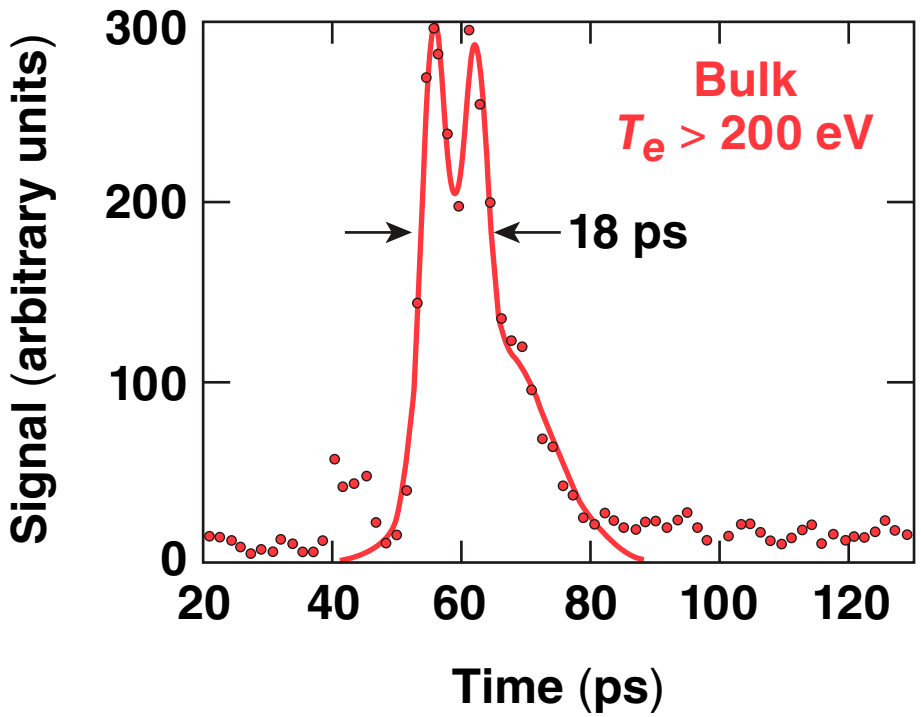
Fast-Electron Energy Deposition In Solid-Density Plasmas

High-Speed X-Ray Streak Camera Data



5-J, 1-ps; 10^{19} W/cm^2
Copper-foil targets

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Summary

Two intense x-ray flashes are resolved from isochorically heated foils in the high-energy-density limit

- The first x-ray flash is caused by fast-electron-induced bremsstrahlung and K-photon emission.
- Thermal radiation from the rapidly heated target bulk causes the second x-ray flash.
- The lag time between the two x-ray flashes is sensitive to the fast-electron temperature.

Dual x-ray flashes provide a stringent test for energy-coupling models.

E17397

Collaborators

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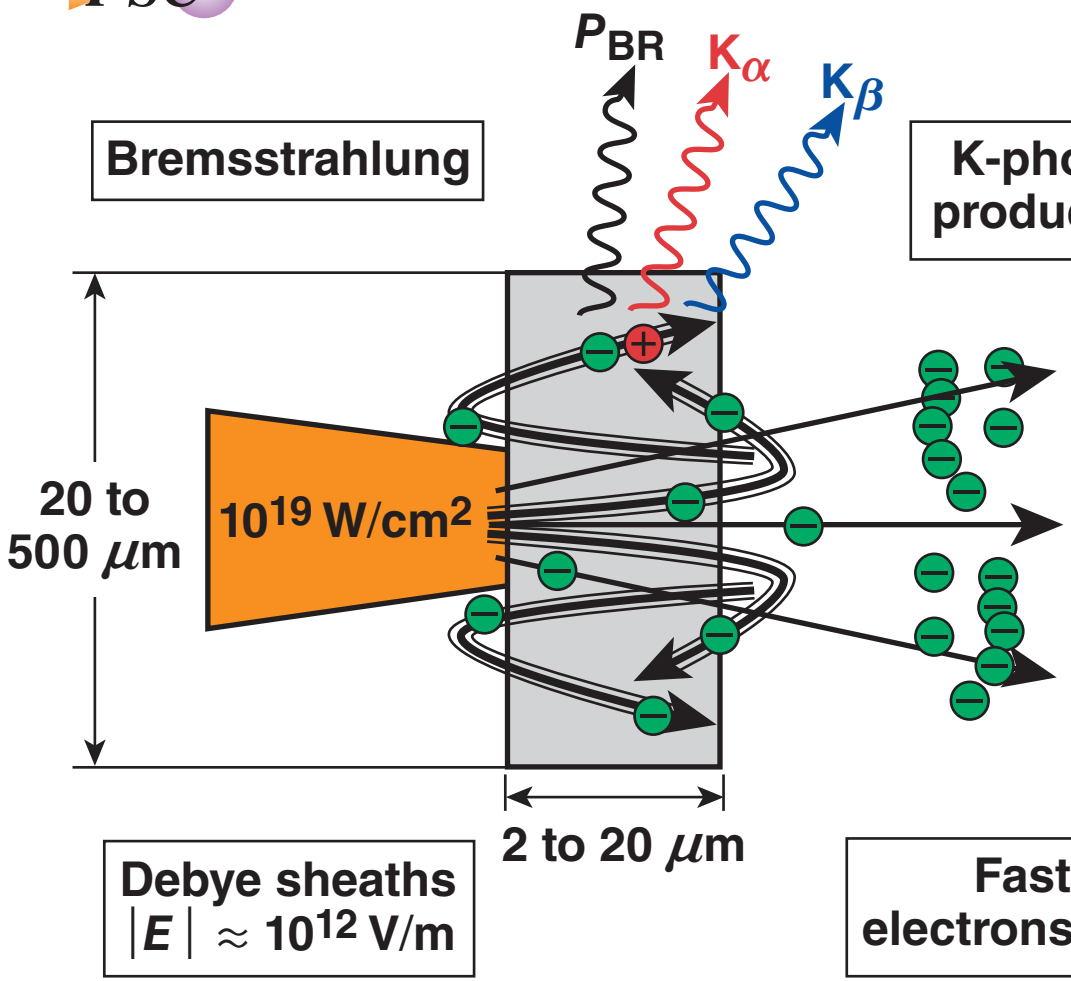
Fast-electron refluxing in small-mass targets allows access to high-energy-density phenomena



- Refluxing is caused by Debye-sheath field effects[1,2]
- Majority of fast electrons are stopped in the target
- Provides a simple geometry for testing laser-coupling, electron-generation, and target-heating models[3,4]

[1]S. P. Hatchett *et al.*, Phys. Plasmas 7, 2076 (2000).
[2]R. A. Snavely *et al.*, Phys. Rev. Lett. 85, 2945 (2000).
[3]W. Theobald *et al.*, Phys. Plasmas 13, 043102 (2006).
[4]J. Myatt *et al.*, Phys. Plasmas 14, 056301 (2007).

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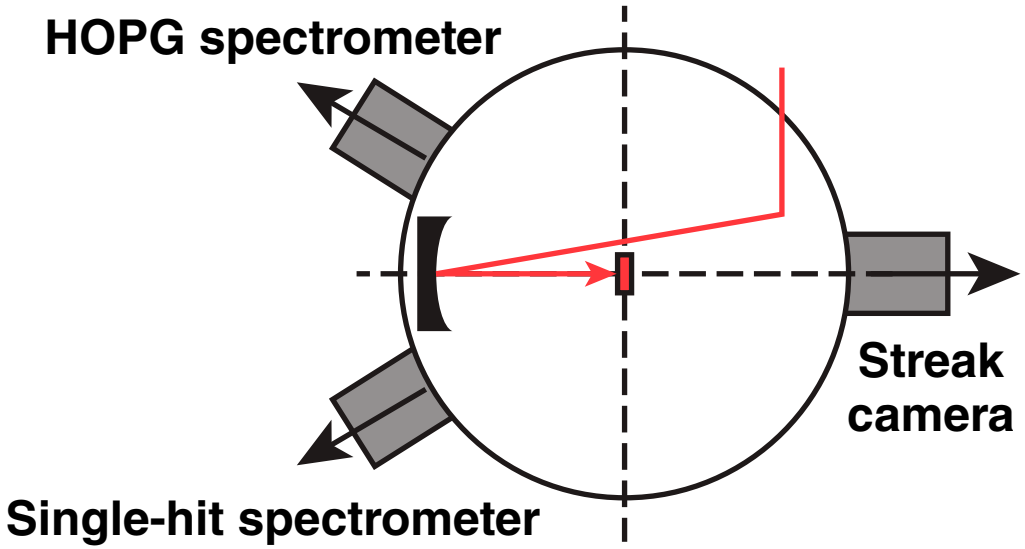
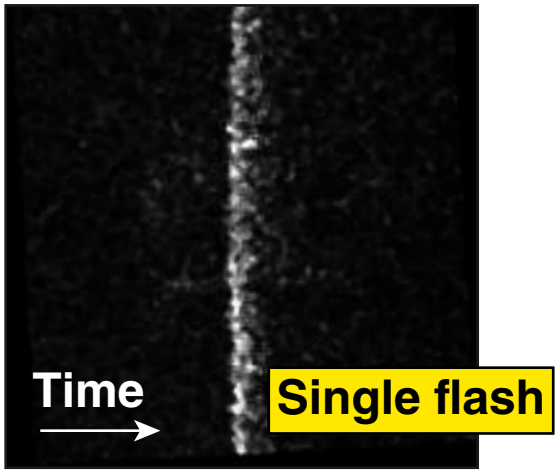
The LLE ultrafast x-ray streak camera time-resolves the x-ray emission

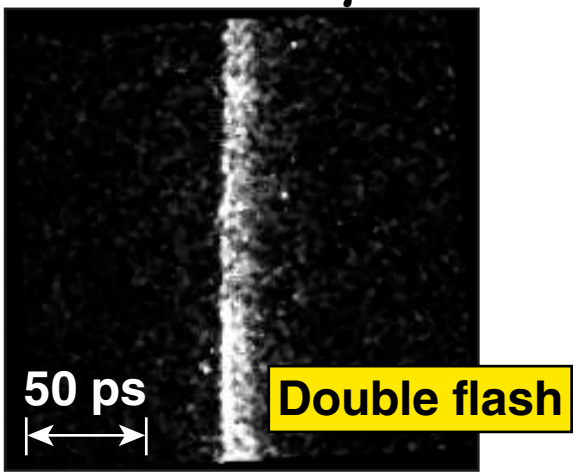
MTW Laser: 5 J, 1 ps; 10^{19} W/cm^2



$500 \times 500 \times 20\ \mu m^3$



$100 \times 100 \times 2\ \mu m^3$



- Streak camera specifications:
  - 10 lp/mm spatial resolution
  - 2-ps temporal resolution
  - KBr photocathode
  - filtered sensitivity > 1 keV

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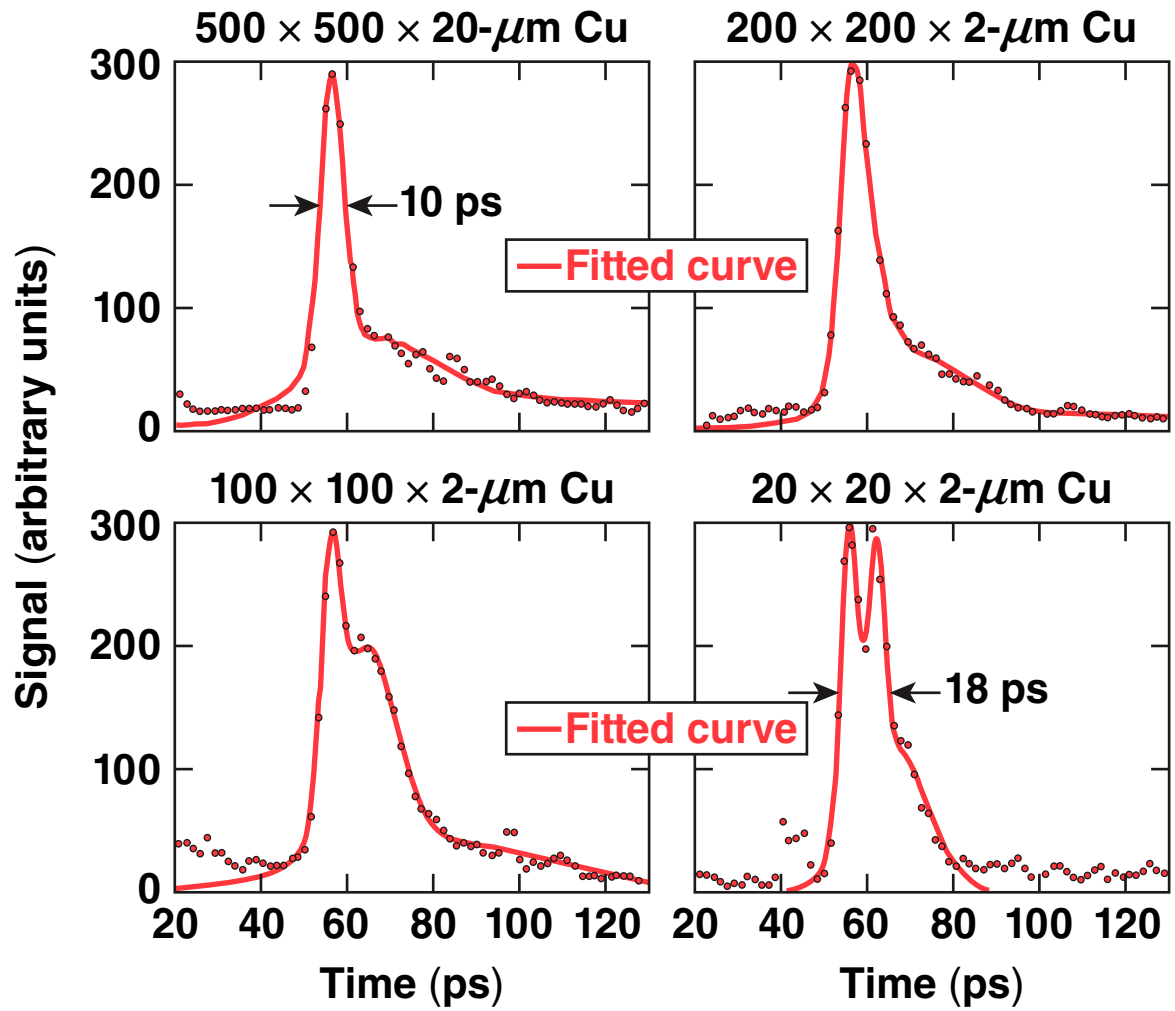
A “double-flash” of radiation >1 keV is observed as the target volume is reduced

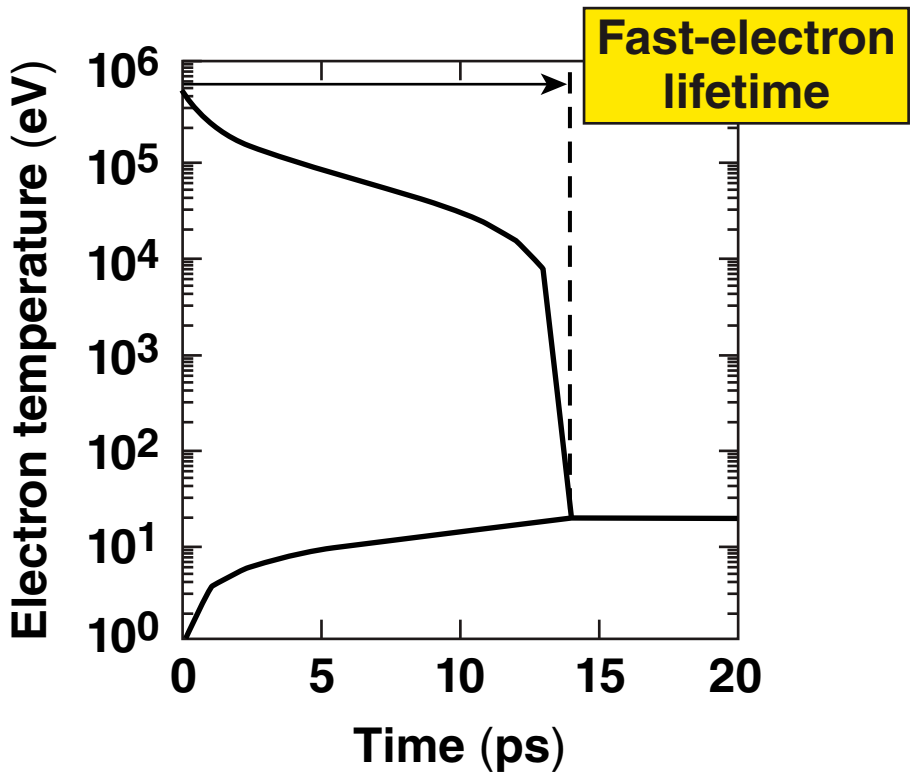
- Bremsstrahlung and K-photon emission dominate in the cold limit.
- As target volume reduces, the plasma energy density increases.



E16839a

The fast-electron lifetime is governed by collisions with thermal electrons and adiabatic ion-front expansion

- 1-D energy relaxation model*
  - electron-electron collisions
  - adiabatic expansion cooling
- Initially cold, 20-μm-thick copper foil
- Fast-electron-energy loss causes heating to tens of electron volts

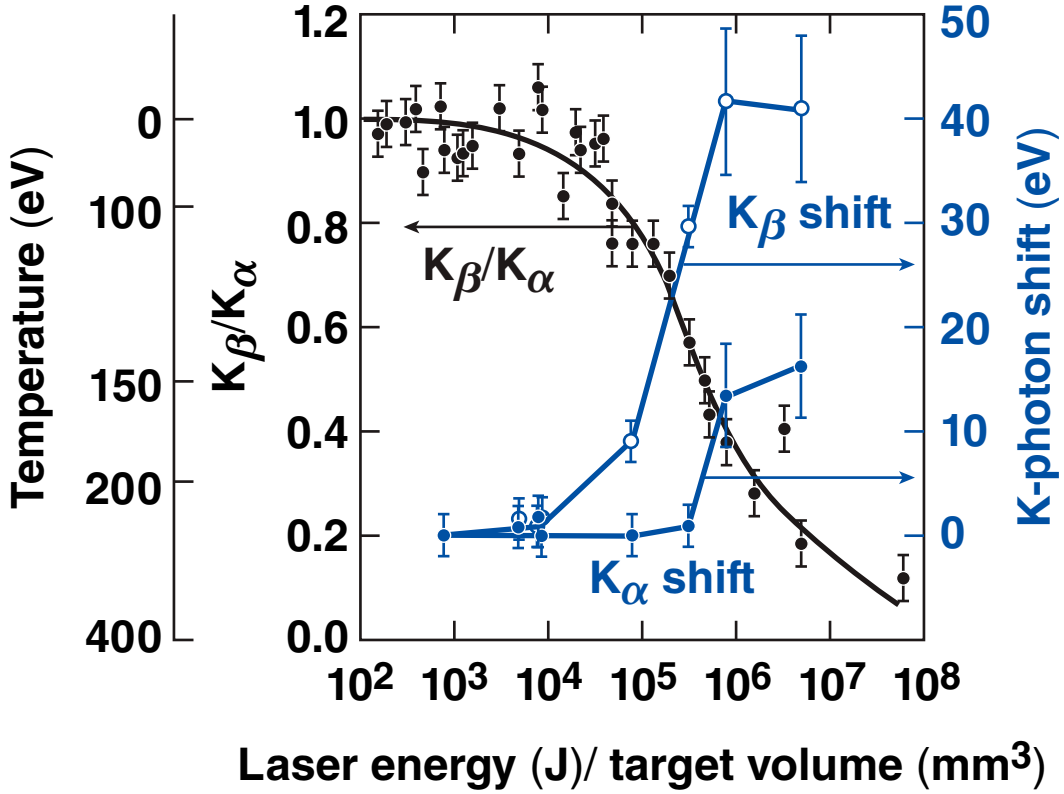


*H. Chen *et al.*, Phys. Rev. E 76, 056402 (2007).

E17399

High bulk-electron temperatures in small mass targets are confirmed by K-photon spectroscopy

- Inelastic electron-electron collisions heat the target
- Collisional ionization with the thermal background occurs
- L- and M-shell depletion at high bulk-electron temperatures causes spectral line shifts* and K_β/K_α suppression**

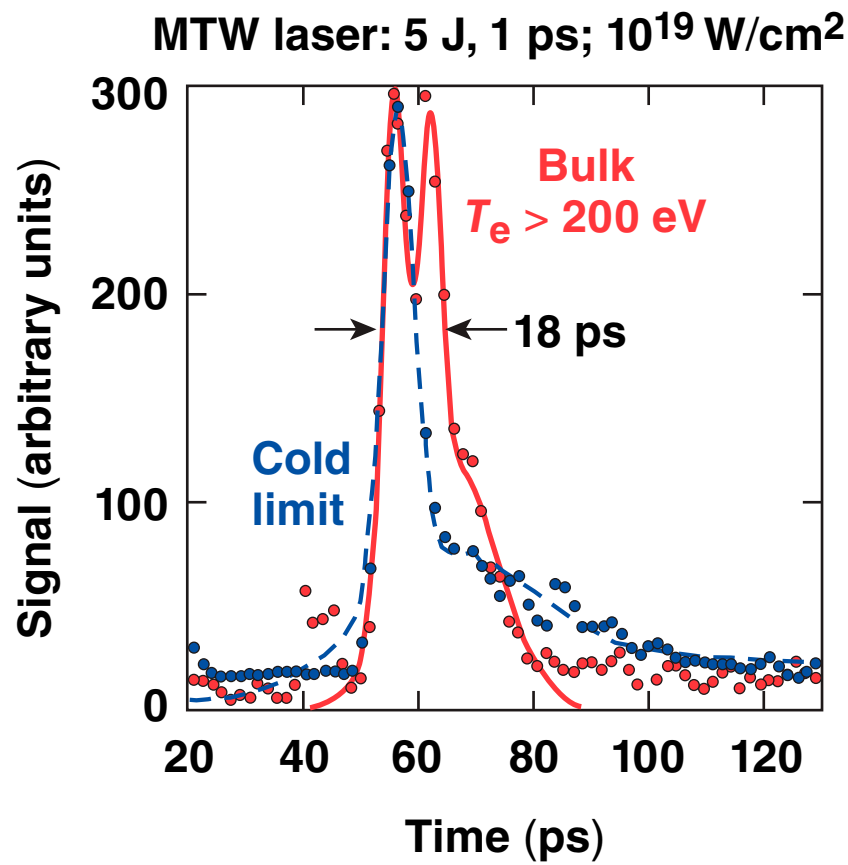


* G. Gregori *et al.*, Contrib. Plasma Phys. 45, 284 (2005).
** P. M. Nilson *et al.*, Phys. Plasmas 15, 056308 (2008).

E17400

Two x-ray flashes are resolved from targets that are heated to the highest bulk-electron temperatures

- The first x-ray flash is induced by fast electrons losing energy in initially cold target material
- The second x-ray flash is a finite-time isochoric heating effect not observable in the cold material limit
- Thermal emission > 1 keV is consistent with the inferred bulk-electron temperatures



* G. Gregori *et al*., Contrib. Plasma Phys. 45, 284 (2005).
** P. M. Nilson *et al*., Phys. Plasmas 15, 056308 (2008).

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Summary/Conclusions

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