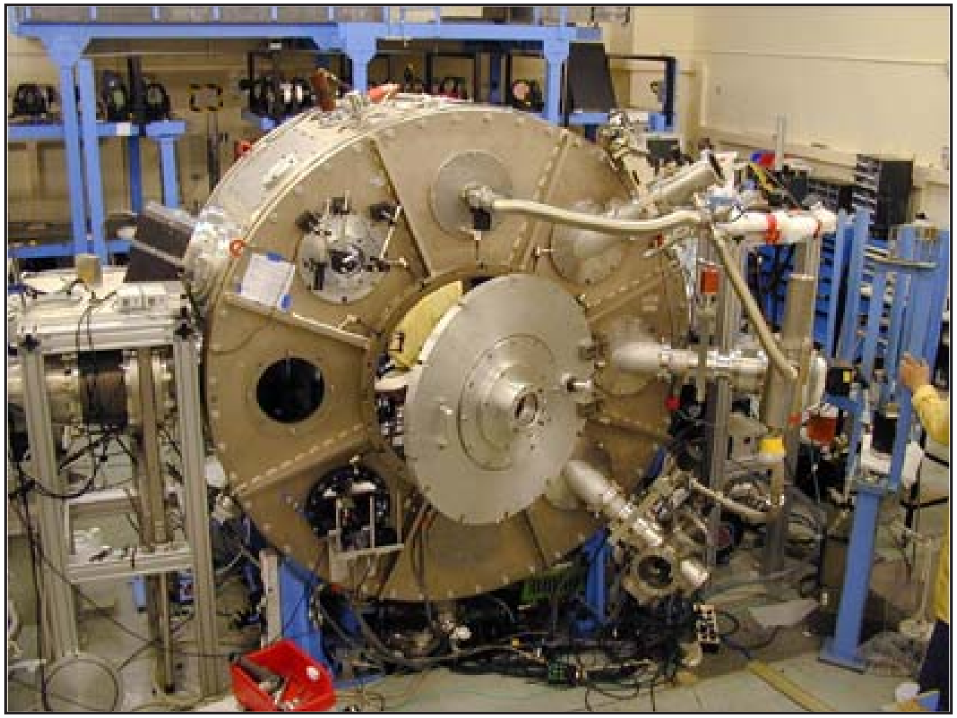
X-Ray Line Emission Spectroscopy of 100 TW Laser-Pulse-Generated Plasmas for Backlighter Development of Cryogenic Implosion Capsules



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Summary

The 100-TW laser backlighter experiment yields ~40 μJ/eV/ps at 1.6 keV photon energy

- A peak spectral energy density of ~4 mJ/eV is measured for thermal aluminum *K*-shell emission assuming isotropic emission.
- Emission times of ~100 ps are estimated by comparing the simulated brilliance with the measurements for a fixed source area.
- Spectral power densities of ~800 μJ/eV/ps at 2 keV are required for backlighting cryogenic implosion targets. The brightness needs to be increased by a factor of ~20.
- Electron temperatures and densities of up to $T_e \sim 400$ eV and $N_e \sim 8 \times 10^{22}$ cm^{-3}, respectively, are estimated.

Backlighting of cryogenic implosion targets requires spectral bright, ultrashort x-ray flashes

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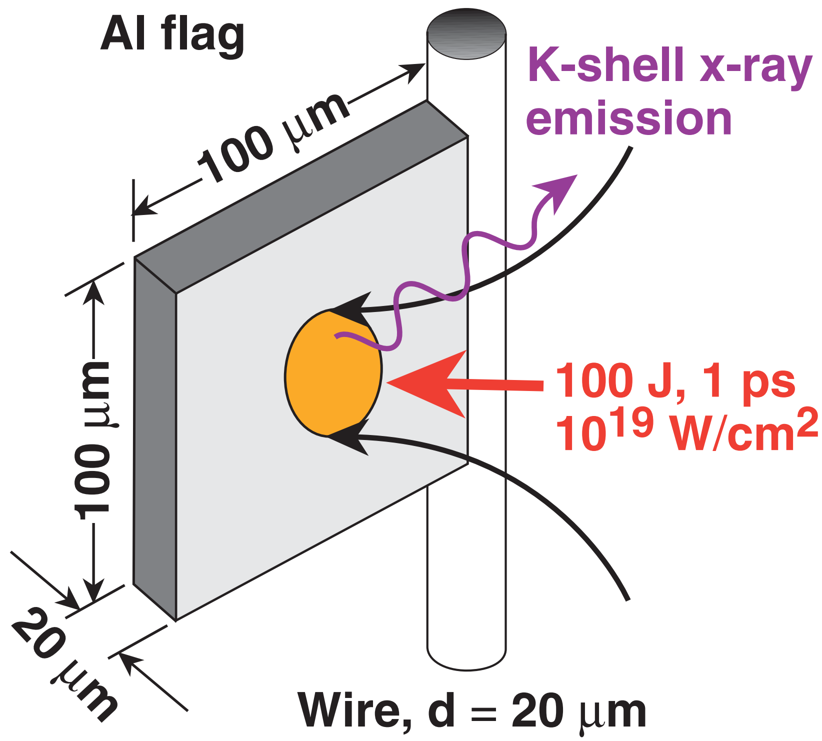
- Simulations show that a backlighter spectral brightness of ~ 800 μJ/eV/ps at 2 keV has to be achieved in order to overcome the target self-emission.
- The photon energy of 2 keV allow optimum imaging contrast for a T = 1 keV, ρr = 200 mg/cm^2 core at stagnation.
- A minimum gating time of 20 ps is considered to minimize the contribution by target self-emission.
- High-power, high-energy beams from OMEGA EP will be used for backlighting OMEGA cryogenic target implosions:

Intensity range:	10^{16} to 10^{18} W/cm^2
Laser pulse duration:	10 ps
Pulse energy:	2.6 kJ

Flag targets were irradiated with the 100-TW laser



- Pulse energy: ~100 J
- Pulse duration: 1 ps to several ps
- Laser wavelength: 1.053 μm
- Focus diameter (*f*/3 parabola): ~ 10 μm
- Normal incidence
- Shot 0406031: ~ 10^{17} W/cm^2
- Shot 0406045: ~ 10^{19} W/cm^2

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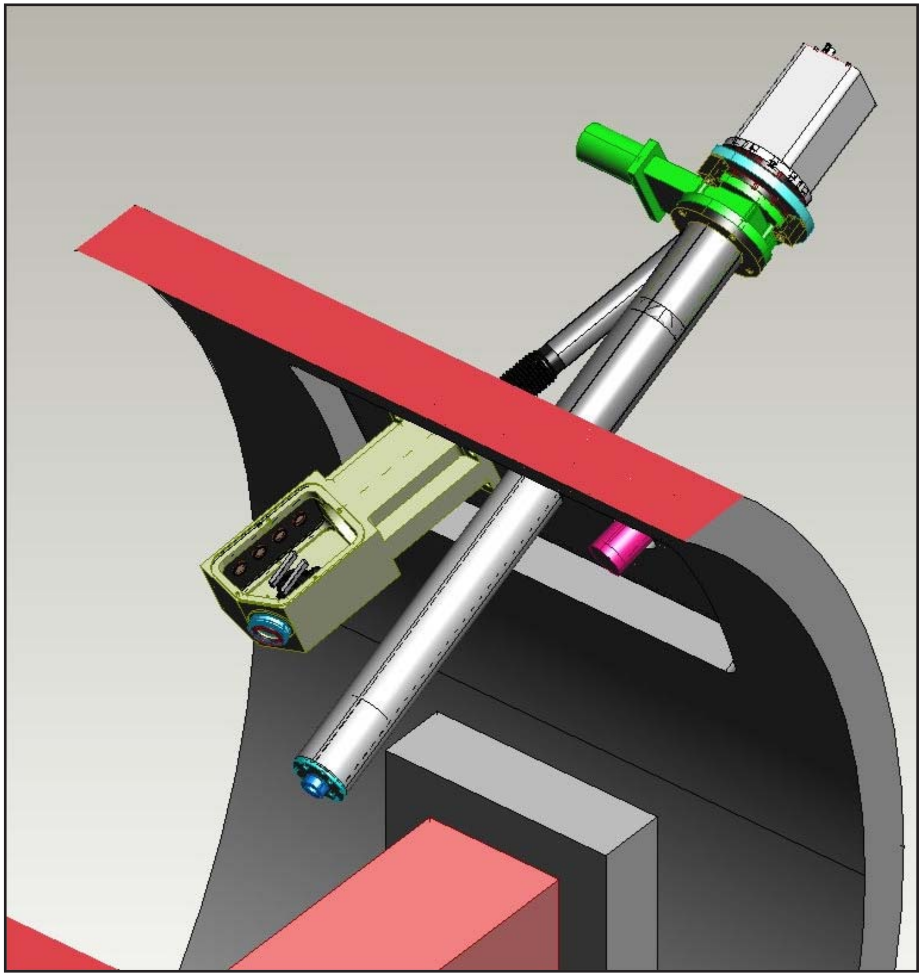
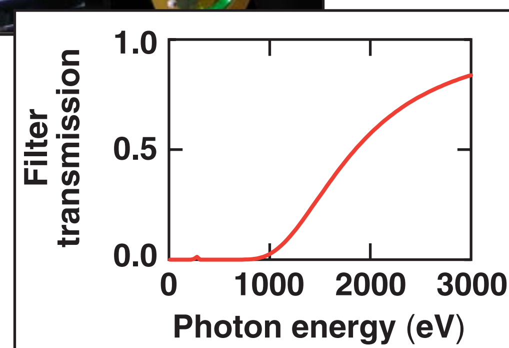
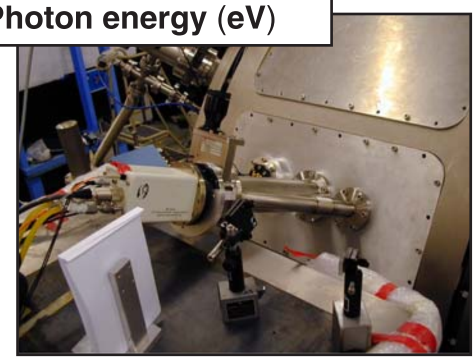
A dual channel, flat-crystal spectrograph with a single hit x-ray ccd camera records the Al *K*-shell emission



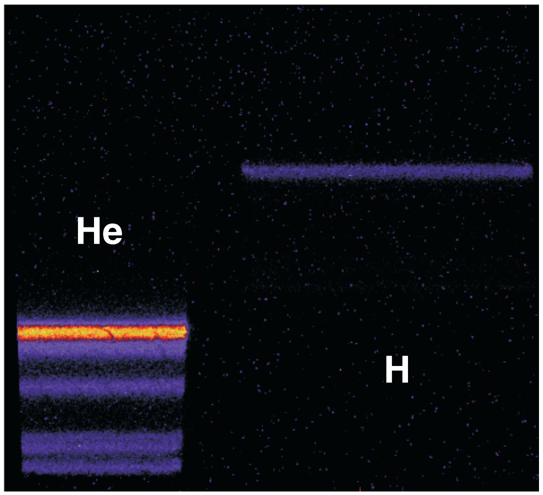




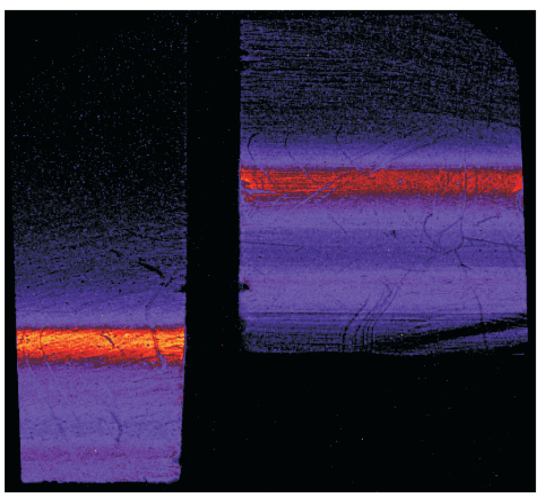
See also: C. Stoeckl (EO1.012)
J. Kuba (EO1.008)

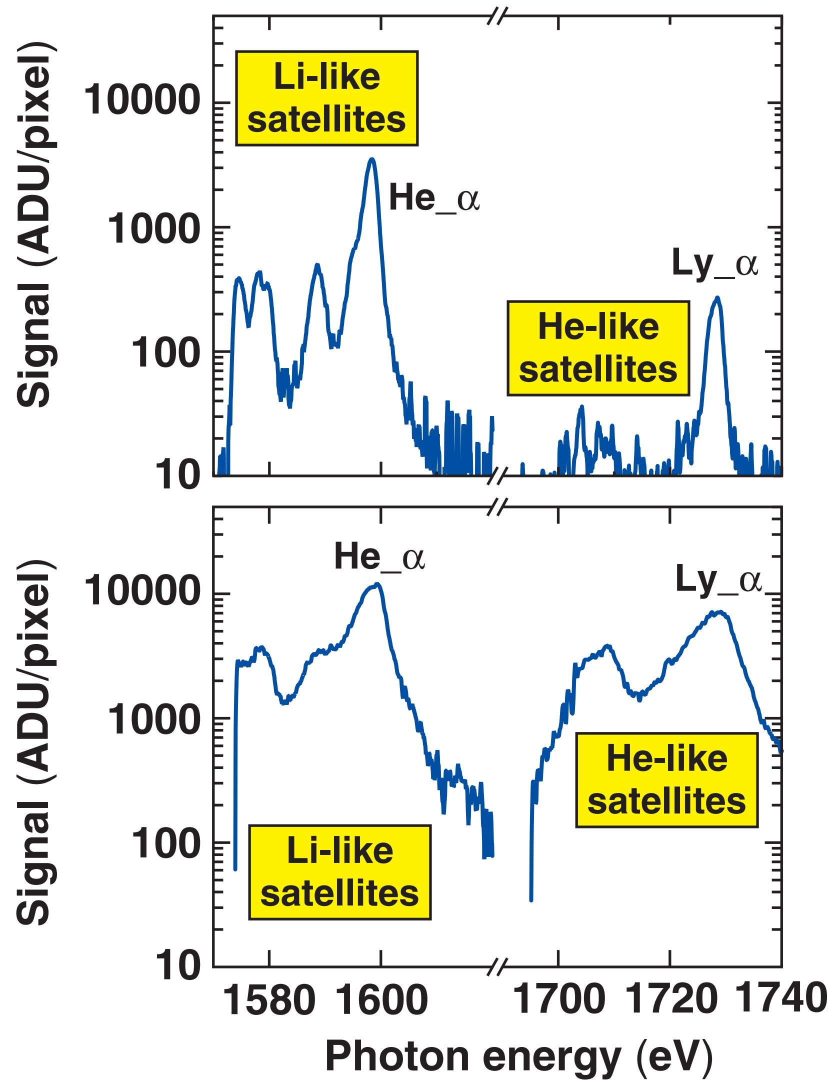
A strong increase in the Al H-like *K*-shell emission is observed with increased laser intensity

Shot 0406031 ~ 10^{17} W/cm^2



Shot 0406045 ~ 10^{19} W/cm^2





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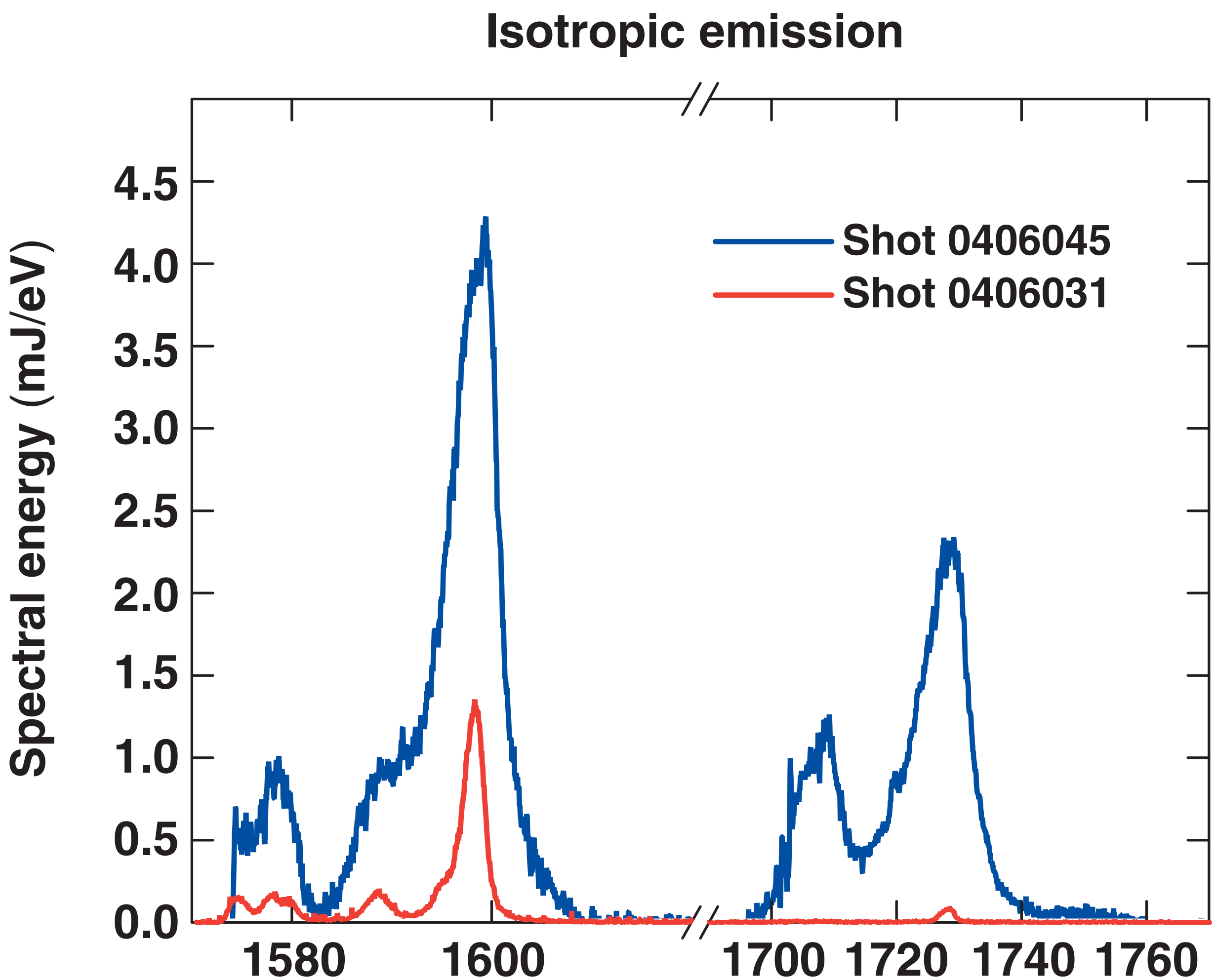
The measurement yields peak spectral energy densities of 4 mJ/eV at 1.6 keV



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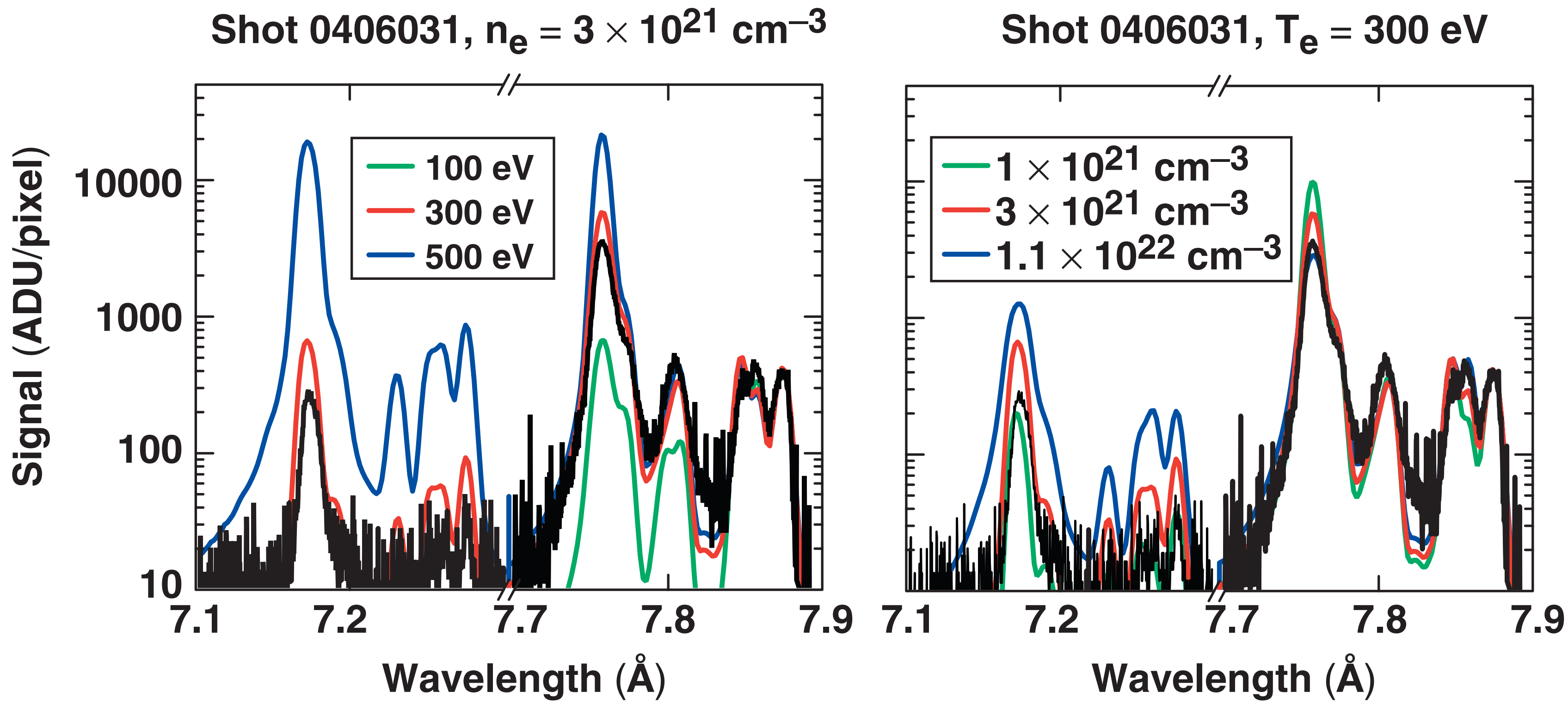
The thermal aluminum *K*-shell emission was compared to simulations of the program PrismSPECT*



- The estimated temporally and spatially averaged electron temperature and density are ~300 eV and $n_e = 3 \times 10^{21}$ cm^{-3}, respectively.

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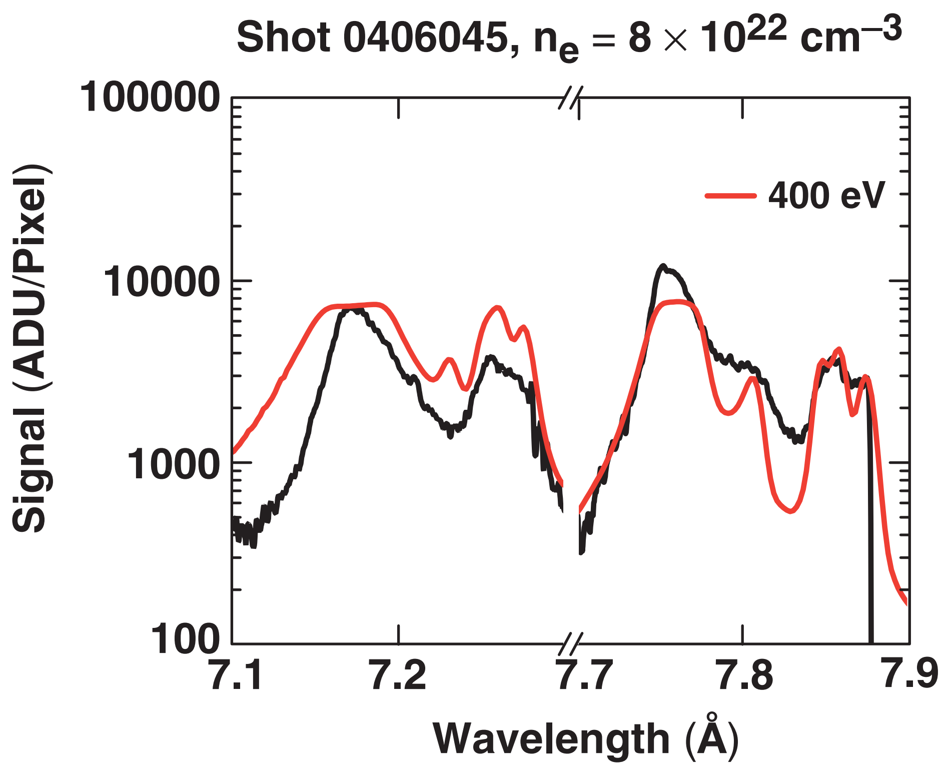
* J. J. MacFarlane, *et al.*, Prism Computational Sciences, Madison, WI 53711

The analysis of Shot 0406045 yields a density increase by a factor of ~30 and a slightly higher temperature

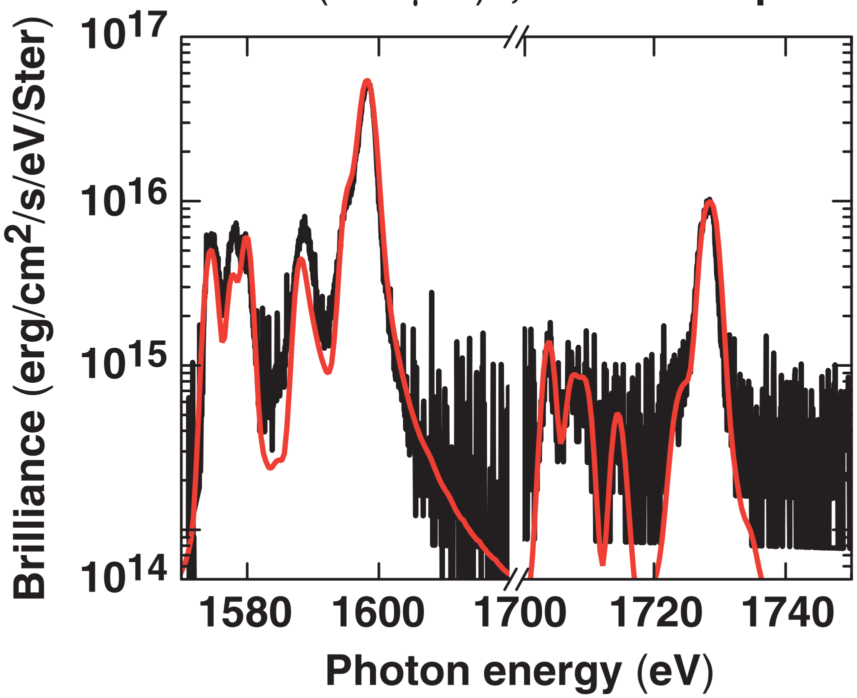


- An average temperature of ~400 eV and a density of $n_e = 8 \times 10^{22}$ cm^{-3} are estimated.
- Similar plasma parameters were obtained with buried Al layers in PW laser experiments*.

*J. Koch *et al.*, Phys. Rev. E 65, 016410 (2001).

The comparison of the calculated brilliance with the measurement indicates emission times on the order of ~100 ps

Shot 0406031, t = 20 μm
A = (100 μm)^2, τ = 70–200 ps



- Brilliance:

$$B = \frac{E_{ph}}{\Delta\hbar\omega(\mathrm{eV})\ \Delta\Omega} \quad \frac{1}{t \times A}$$

- For Shot 04046031, the source area is known (foil size) ⇒ an emission time of ~100 ps is estimated.
- Aluminum *K*-shell emission times of 70 ps were measured in PW laser irradiated solid target experiments*.
- Emission times in the 2 keV range need to be measured with a streaked x-ray spectrograph.

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*J. Koch *et al.*, Phys. Rev. E 65, 016410 (2001).

Summary/Conclusions

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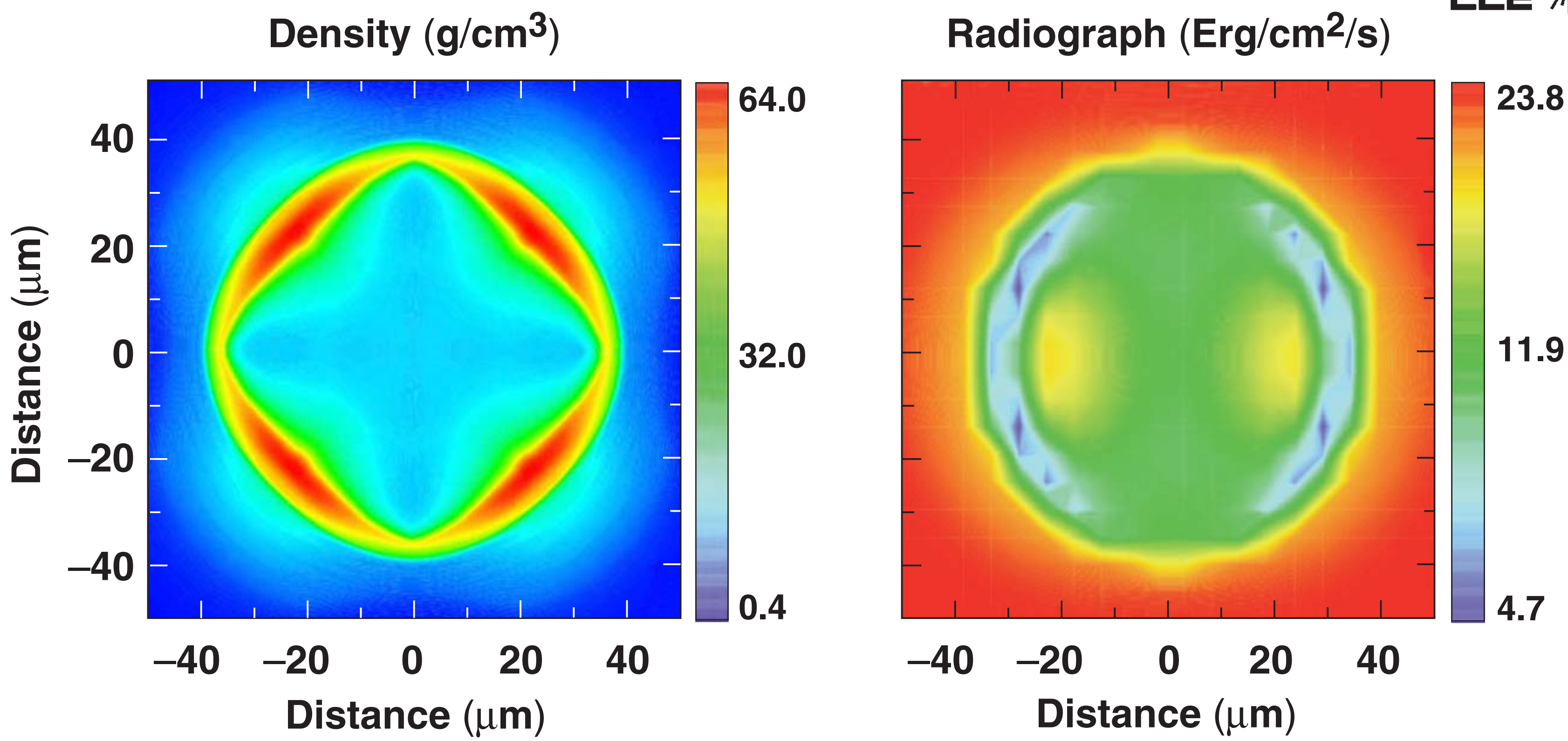
- Electron temperatures and densities of up to $T_e \sim 400$ eV and $N_e \sim 8 \times 10^{22}$ cm^{-3}, respectively, are estimated.

A backlighter spectral power density of 800 μJ/eV/ps in the 2 keV spectral range is required for imaging



- Simulations predict a self-emission of 100 μJ/eV/ps into 4π in the 2 keV range.
- The simulation assumes, for the backlighter, a 3 keV Planckian spectrum filtered in the 2 to 2.2 keV spectral range.

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