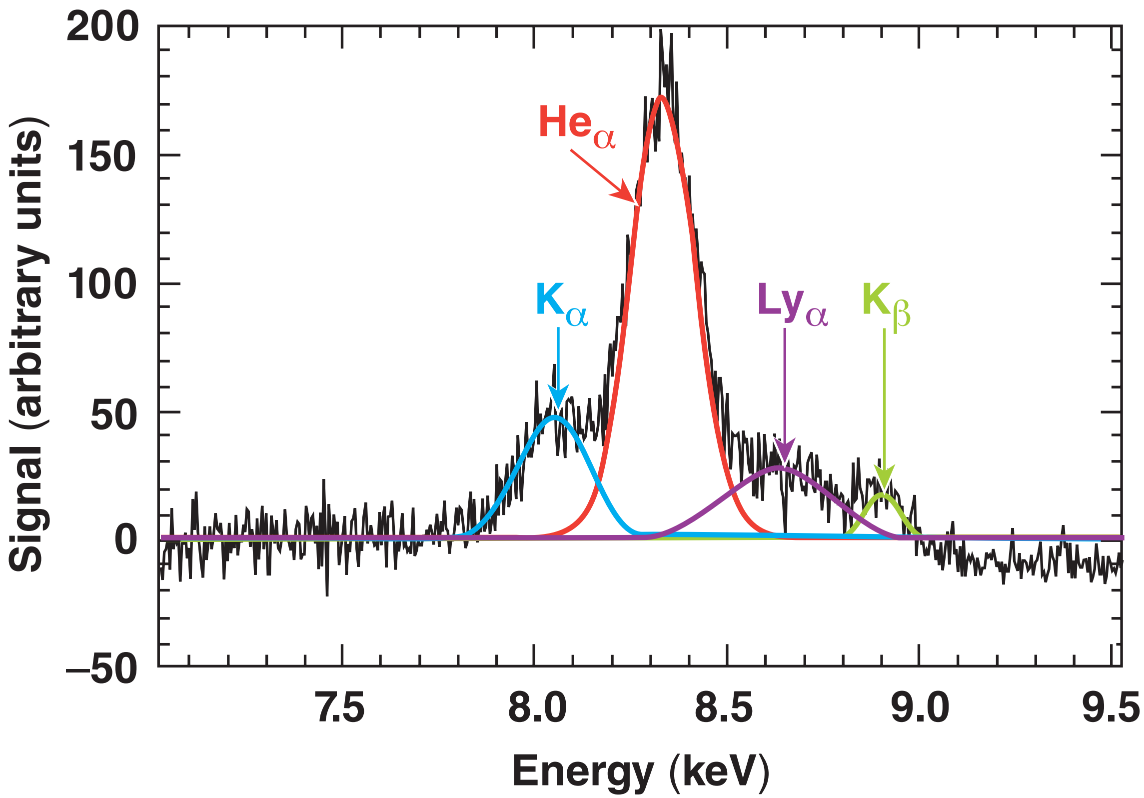
K-Shell Spectroscopy Using a Single-Photon Counting X-Ray CCD in Ultrafast Laser–Plasma Interaction Experiments



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Thermal emission lines in the *K*-spectrum indicate a hot surface layer in ultrafast laser plasma experiments

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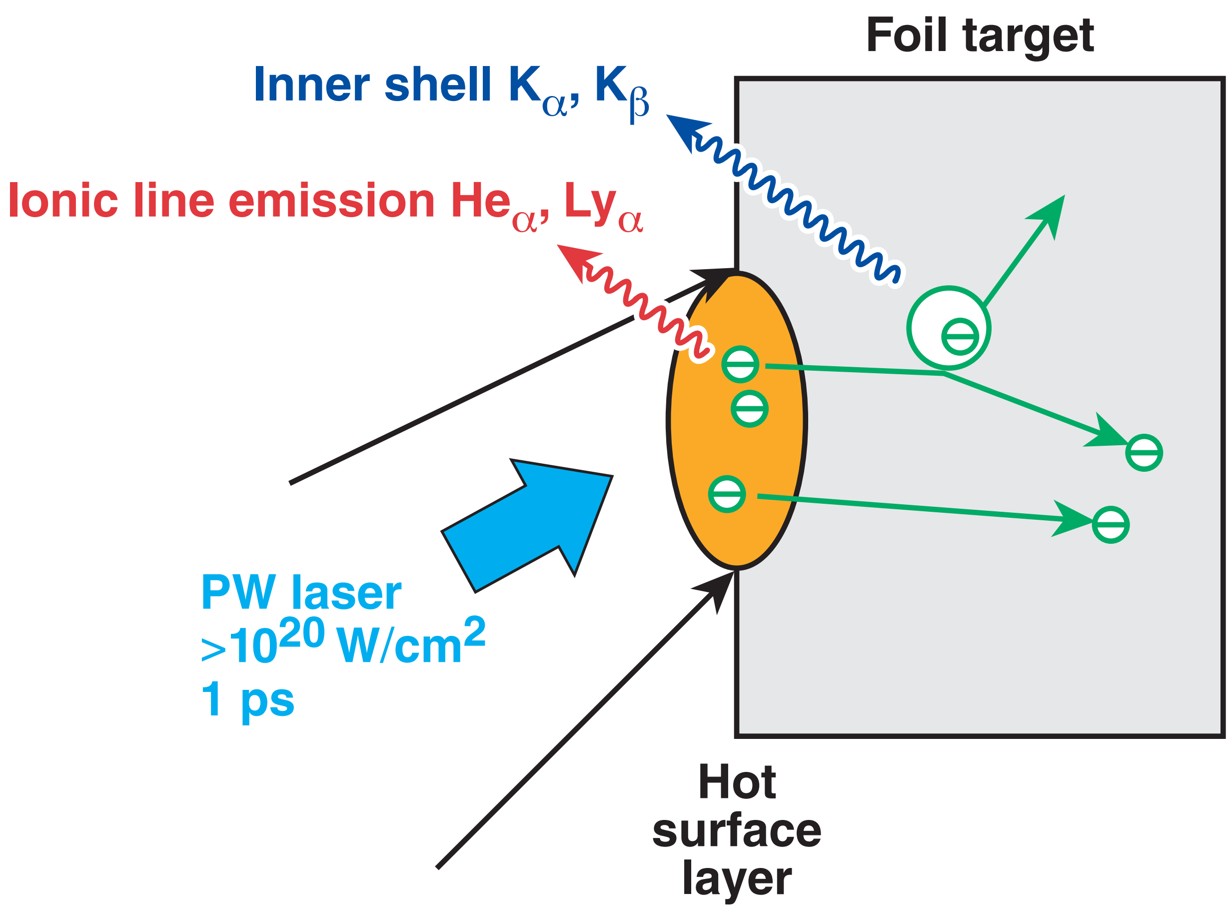
- *K*-shell spectroscopy can be used in ultrafast laser–plasma experiments to infer the conversion of laser energy into electrons, x-rays, and plasma heating.
- An x-ray CCD in single photon counting mode is an attractive option for x-ray spectroscopy up to several 10–keV energy.
- Proper filtration and background suppression is essential to obtain high quality spectra.
- At a laser intensity $>10^{20}$ W/cm^2, thermal emission lines appear in the *K*-shell spectrum of Cu targets.
- A temperature of up to 4 keV in a ~1-μm-thick surface layer can be inferred from the spectra.

K-shell emission can be used to infer the conversion of laser energy into hot electrons



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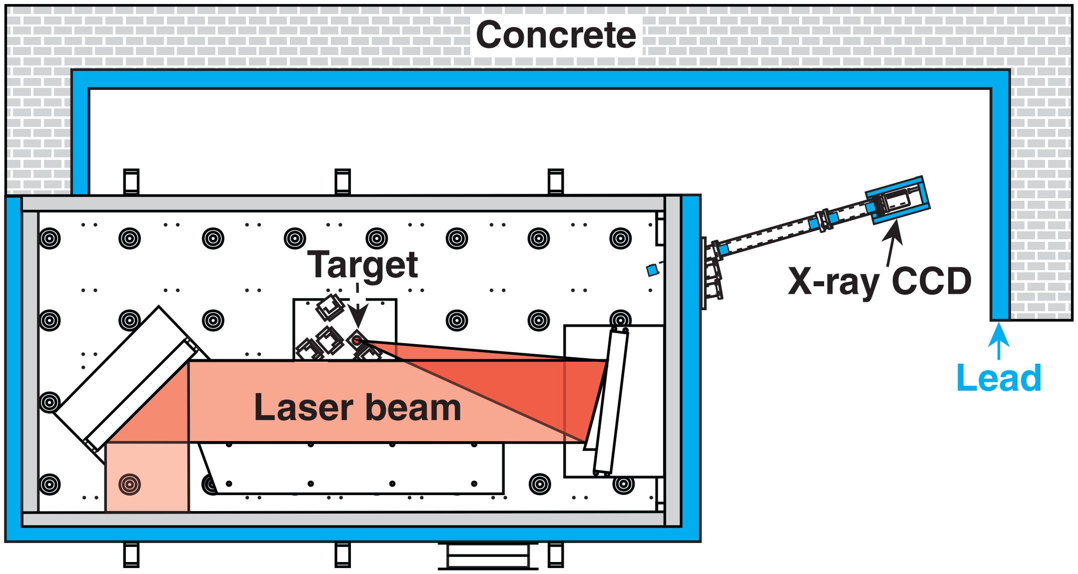
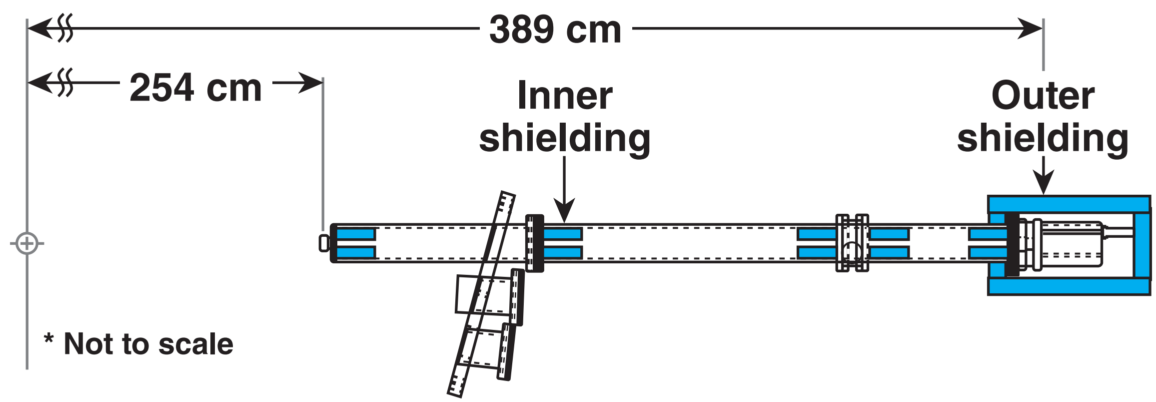
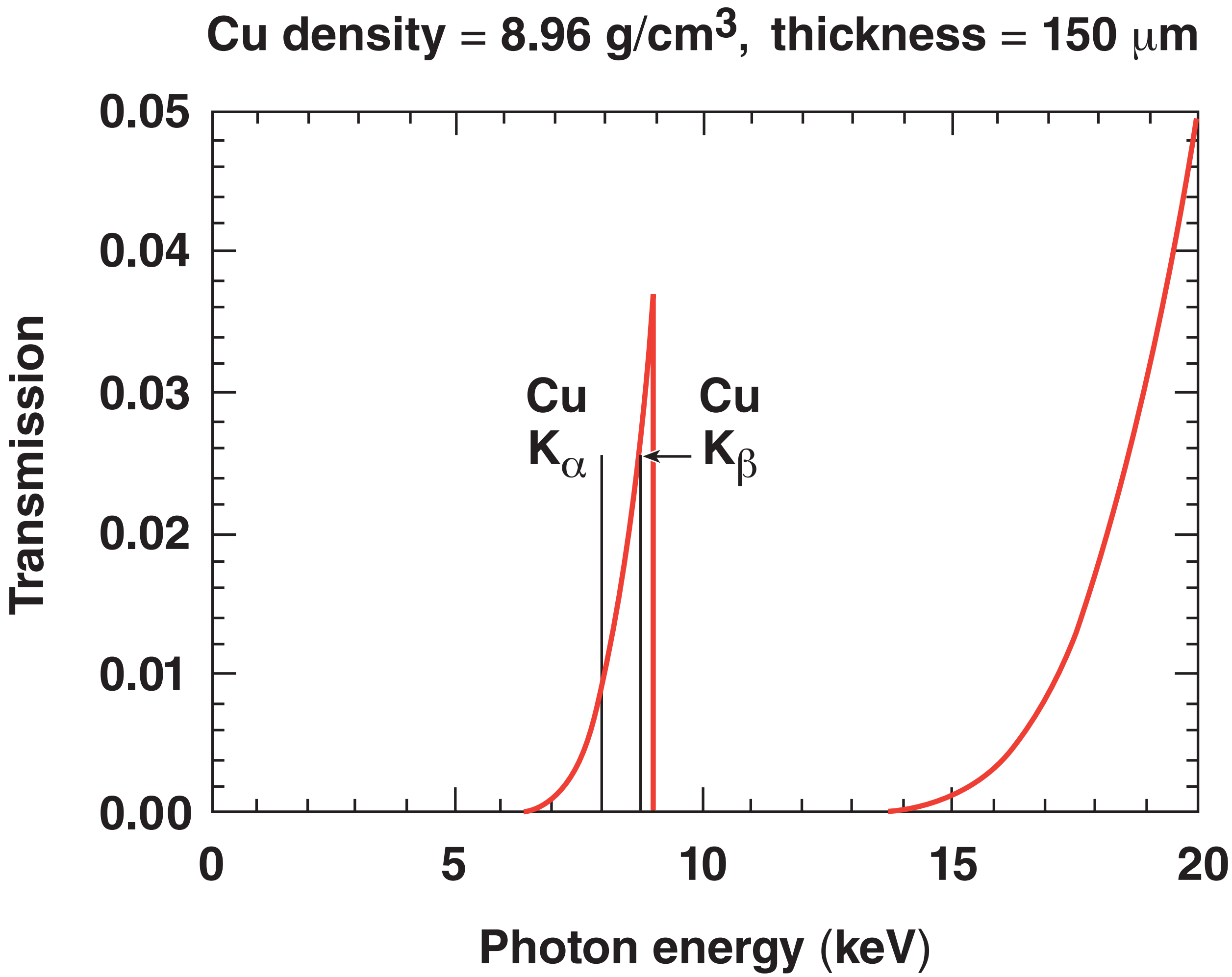
Lead shielding is used to suppress the background from Compton scattering and x-ray fluorescence





A matched *K*-edge filter improves the signal-to-background ratio



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At low intensities, no thermal emission lines are seen in the Cu spectrum

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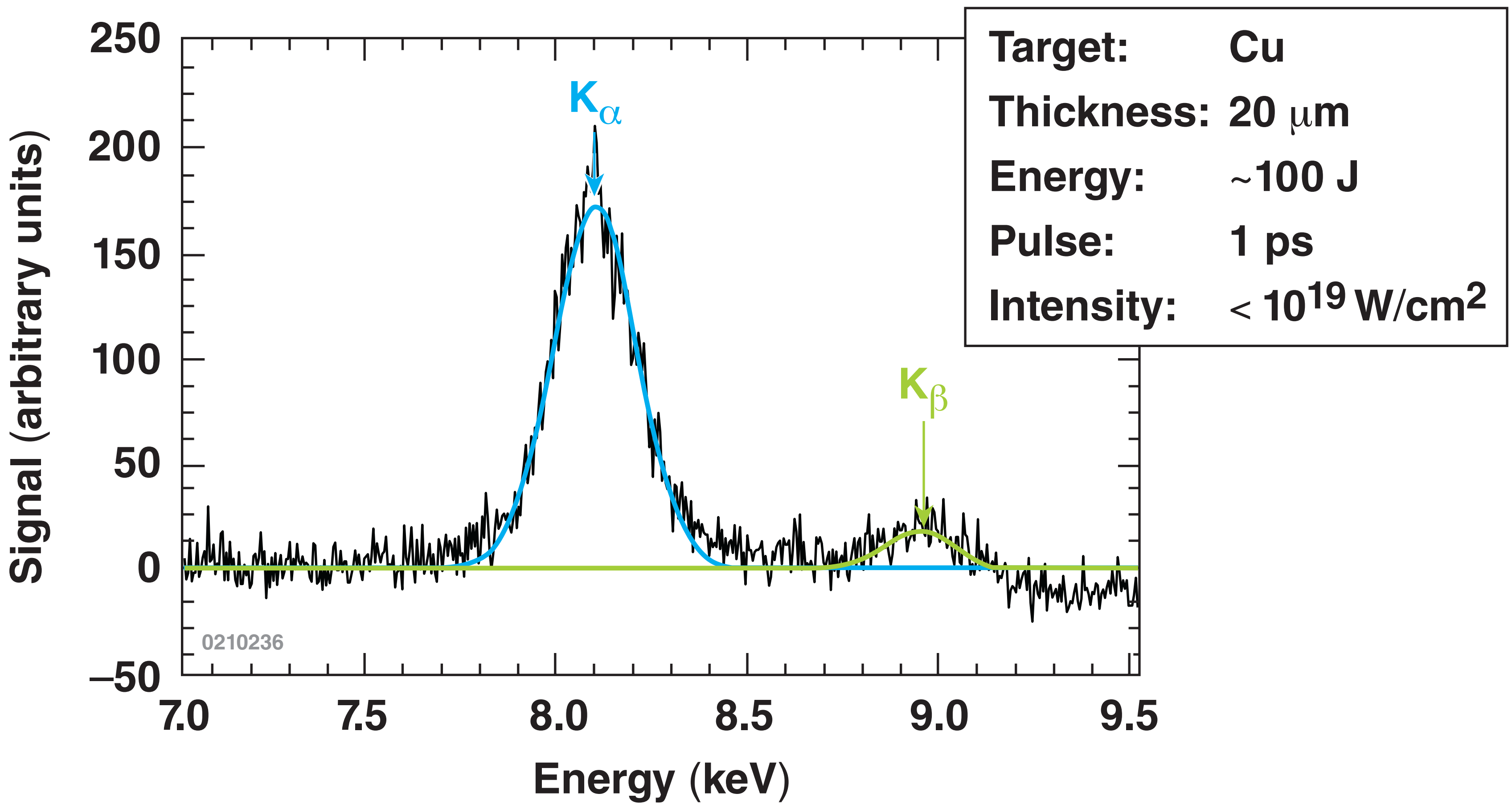
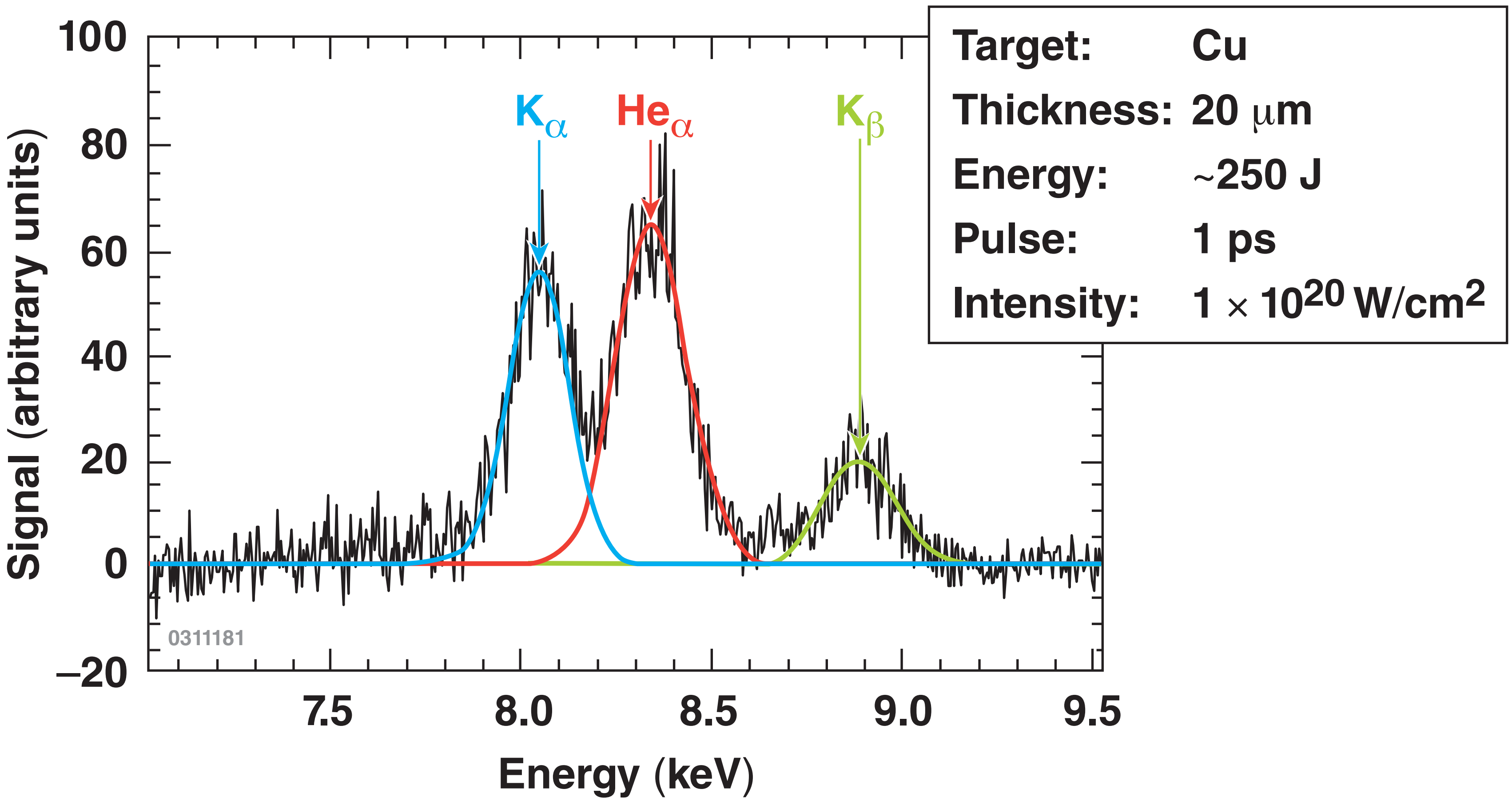


At higher intensities, He_α emission lines are observed in the *K*-shell spectrum



At the highest intensity, Ly_{α} emission lines are seen in addition to the He_{α} lines

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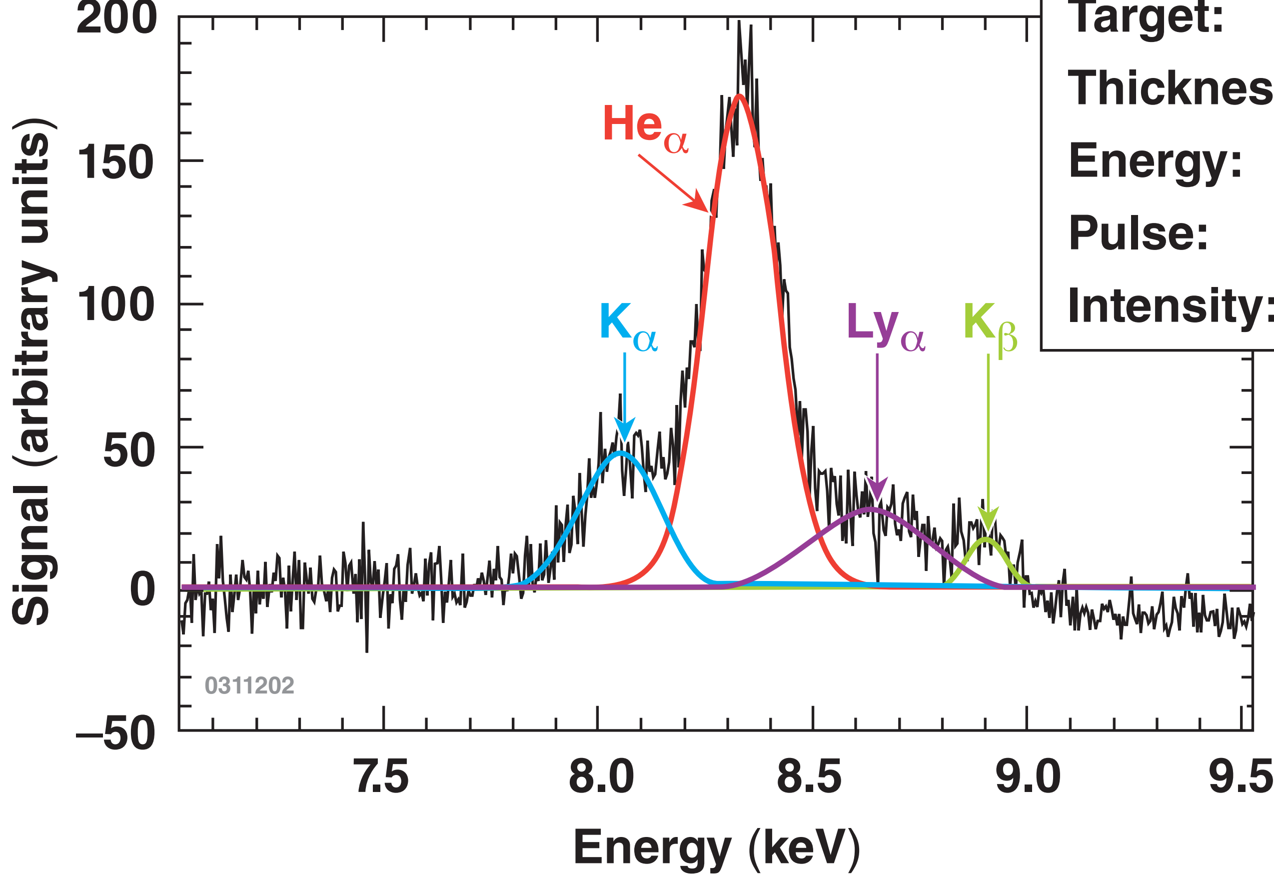

Target:	Cu
Thickness:	20 μm
Energy:	~500 J
Pulse:	1 ps
Intensity:	2×10^{20} W/cm^2

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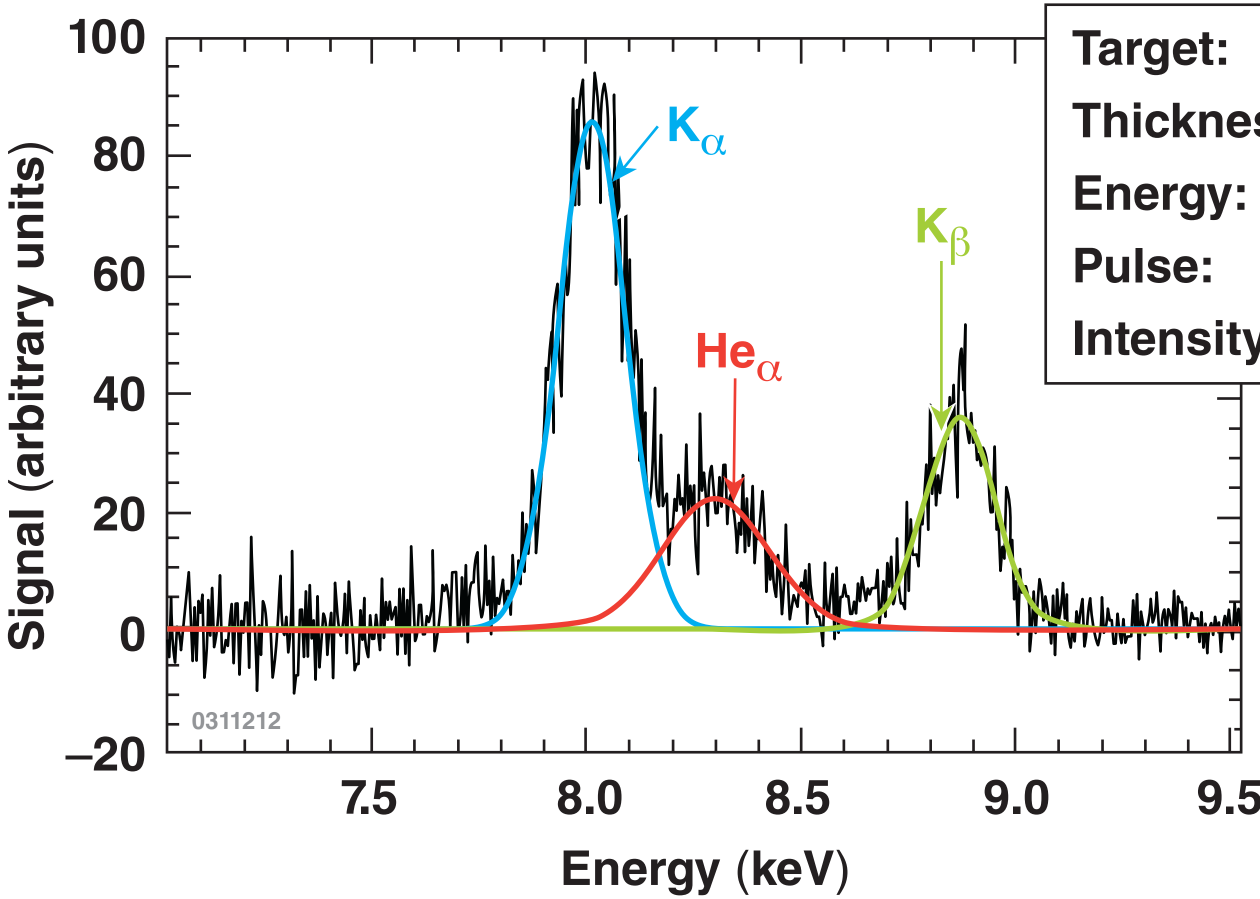
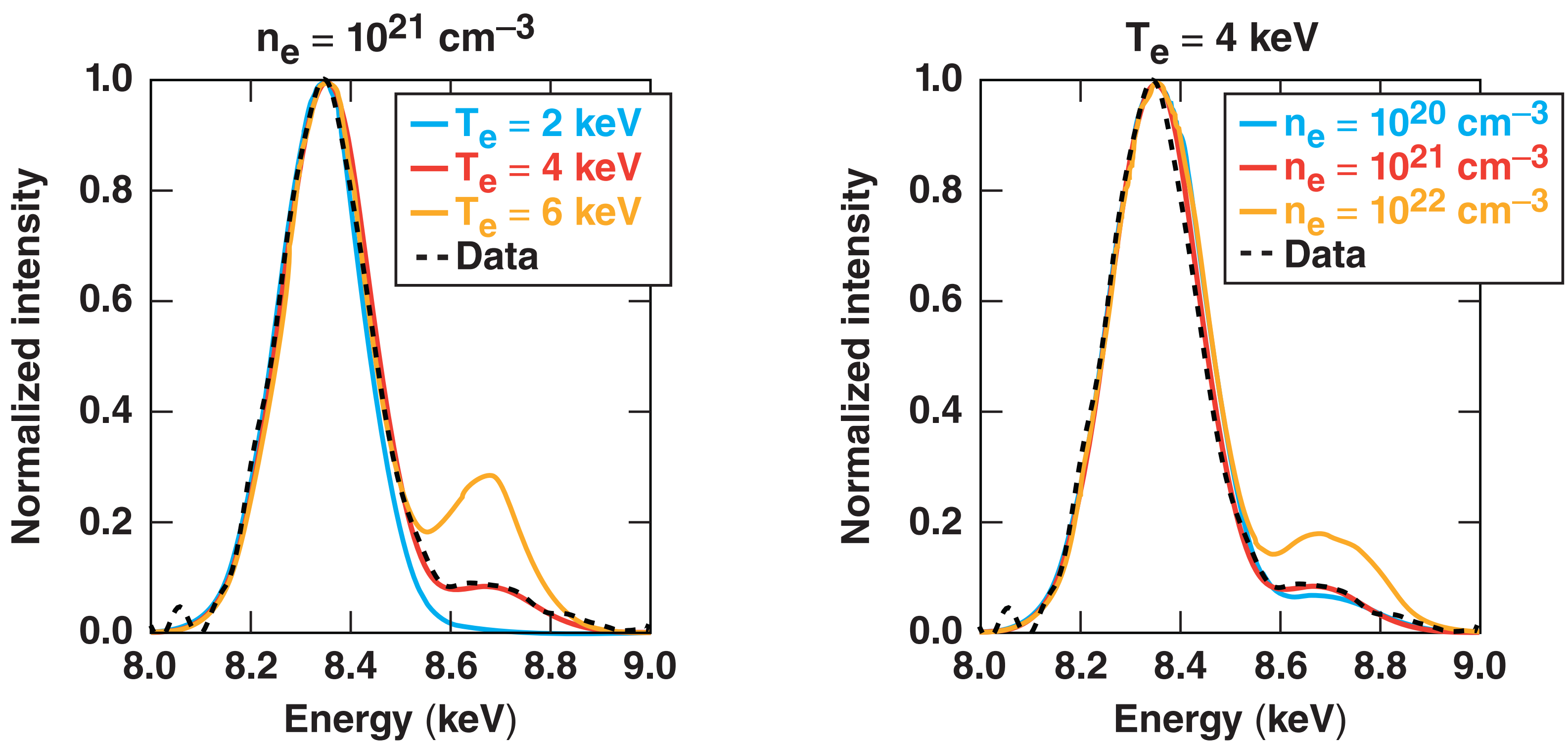
With a 1 μm Al overcoat the thermal emission lines almost disappear, even at high intensity



Target:	Al + Cu
Thickness:	1μm + 20 μm
Energy:	~250 J
Pulse:	1 ps
Intensity:	1×10^{20} W/cm^2

An estimate of the temperature and density can be obtained by fitting the emission spectrum to a model

Best fit: $T_e = (4.0 \pm 0.5)$ keV $n_e = 10^{21}$ cm^{-3}



- Uniform density and temperature model: PrismSPECT*

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As expected, no thermal emission lines can be seen in the *K*-shell spectrum of an Ag target