High-Brightness \sim 2$-keV Source Development for Backlighting of Cryogenic Implosions

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Backlighting of cryogenic-implosion targets requires ultrashort x-ray flashes with a high spectral brightness.

- A spectral brightness of $\sim 60 \mu J/eV/ps/Sr$ of the backlighter at $\sim 2$ keV is required to overcome the target self-emission in cryogenic implosions.

- High-energy beams (up to 2.6 kJ) from OMEGA EP will be used at high intensity ($> 10^{18} \text{ W/cm}^2$) for backlighting.

- Short-pulse experiments with up to 500 J of energy show promising results, with measured spectral emissions up to $1.8 \text{ mJ/ev/Sr}$.

- Time-resolved spectroscopy is required to measure the spectral brightness without relying on assumptions of the emission time.
Collaborators

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A backlighter spectral brightness of \( \sim 60 \, \mu \text{J/eV/ps/Sr} \) in the 2-keV spectral range is required for imaging.

- Simulations predict a self-emission of \( 8 \, \mu \text{J/eV/ps/Sr} \) in the 2-keV range.
- Current cryogenic experiments show a self-emission of \( \sim 2 \, \mu \text{J/eV/ps/Sr} \).
- The simulation assumes, for the backlighter, a 3-keV Planckian spectrum filtered in the 2- to 2.2-keV spectral range.
Both flag-mounted and spider-web-mounted mass-limited targets were used in the experiments.

- Electron refluxing* in mass-limited targets could improve the conversion efficiency

*P. M. Nilson (YI2.00001)
Experiments were performed at three different laser facilities with energies up to 500 J.

<table>
<thead>
<tr>
<th>Facility</th>
<th>MTW</th>
<th>100 TW</th>
<th>PW</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy</td>
<td>&lt;10 J</td>
<td>&lt;100 J</td>
<td>&lt;500 J</td>
</tr>
<tr>
<td>Pulse</td>
<td>1 ps</td>
<td>10 ps</td>
<td>1 to 10 ps</td>
</tr>
<tr>
<td>Intensity (W/cm²)</td>
<td>&lt;10¹⁹</td>
<td>10¹⁹</td>
<td>&gt;10²⁰</td>
</tr>
</tbody>
</table>
Al K-shell emission is observed between 6.2 Å and 8.2 Å on an x-ray CCD array.

Target: Al foil in spider web
Dimensions: 6 μm × 100 μm × 100 μm
Energy: ~400 J
Pulse: 10 ps
Intensity: ~1.6 × 10^{19} W/cm²
The radiated spectral energy density has been calculated from the measurements.

- Deposited radiation energy in one CCD pixel:
  \[ E_{\text{pix}}(J) = \text{Signal(ADU)} \times \alpha(\text{eV/ADU}) \times (1.6 \times 10^{-19}) \]

- The CCD was calibrated with K\(\alpha\) emission: \(\alpha = (4.56\pm0.01)\) eV/ADU.
  \[ \tilde{E}_{\text{source}}(\text{J/eV}) = \frac{E_{\text{pix}}(J) \left[ 1 + (\Delta \lambda_{\text{res/line}})^2 \right]^{1/2}}{\text{QE} \times T_{\text{filt}} \times \eta_{\text{cryst}} \times \eta_{\Delta \Omega} \times \Delta(\hbar \omega)_{\text{pix}}(\text{eV})} \]

- The quantum efficiency (QE) of a CCD is assumed to be 100%.
- The filter transmission, \(T_{\text{filt}}\), and the crystal diffraction efficiency \(\eta_{\text{cryst}}\) were taken into account.
- The solid angle \(\eta_{\Delta \Omega}\) was obtained from the rocking curve width.
- The spectral range per pixel is given by \(\Delta(\hbar \omega)_{\text{pix}}(\text{eV})\)
The He$\alpha$ line is much brighter than the K$\alpha$ line at these photon energies.

Target: Al foil in spider web
Dimensions: 6 $\mu$m $\times$ 100 $\mu$m $\times$ 100 $\mu$m
Energy: $\sim$400 J
Pulse: 10 ps
Intensity: $\sim$1.6 $\times$ $10^{19}$ W/cm$^2$
The emitted spectral energy \((\text{mJ/eV/Sr})\) is a function of the laser energy.
A 2-ps time-resolution, ultrafast x-ray streak has been developed and is being tested.

Specifications:
- 10 lp/mm spatial resolution
- 2-ps temporal resolution
- 0.5-ns and 2-ns streak window
- 10-ps rms trigger jitter
Summary/Conclusions

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