The Influence of Smoothing by Spectral Dispersion on Cross-Beam Energy Transfer

OMEGA cryogenic implosions: ~860 μm diam, 8 to 10 μm CH, ~60 μm DT ice

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Scattered-light powers and absorption are essentially unaffected by smoothing by spectral dispersion (SSD) bandwidth

- Scattered-light spectra are qualitatively affected by large SSD bandwidth (1 THz)
- Scattered-light spectra for $\lesssim 0.3$-THz SSD bandwidth are only minimally affected
- Hydrodynamic (LILAC) predictions for scattered-light powers and absorption are very close to experimental observations
- Predicted scattered-light spectra for $\lesssim 0.3$ THz are close to experimental observations
- For 1-THz SSD the measured spectral shifts indicate cross-beam energy transfer (CBET) occurs at higher densities without affecting scattered powers and absorption
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Broadband SSD can influence the CBET interaction region (density)

Optimum CBET region depends on color combinations near Mach = 1 (~n_c/4)

- Flow and density gradient are generally antiparallel
- As a result of electromagnetic (EM) seeding, only very small stimulated Brillouin scattering (SBS) gains are required
SSD at 0.3 THz smooths the scattered-light spectra but hardly affects the overall spectral shapes or scattered-light powers

Experimental scattered-light spectra are inherently broadened by the plasma by

- Dewandre shifts caused by different time-dependent ray paths in the corona (most effective at early times)
- Self-phase modulation, SBS forward scattering, filamentation, etc., in the plasma
Basically, 0.3-THz SSD does not affect the measured spectral shapes, powers, or integrated absorption values.

\[
0.3-\text{THz SSD}, I_{14} = 7.2
\]

\[
\text{No SSD, } I_{14} = 6.5
\]

Experimental absorption = 68%
One-dimensional hydrodynamic simulations (*LILAC*) very well reproduce scattered-light powers and energies.
Scattered-light powers for 0.3- and 0-THz SSD are practically indistinguishable

- **0.3-THz SSD, $I_{14} = 7.2$**
  - Red shift
  - Experimental spectrum
  - $\log(I)$
  - 50 5% contours

- **No SSD, $I_{14} = 6.5$**
  - Experimental spectrum
  - $\log(I)$
  - 50 5% contours

**Experimental absorption** = 68%

- **LILAC absorption** = 70%

- **LILAC absorption** = 72%

- Power normalized to incident

- Time (ns)
LILAC also very well reproduces the scattered-light spectra for 0- and 0.3-THz SSD

0.3-THz SSD, $I_{14} = 7.2$

Red shift

Experimental spectrum

$\Delta \lambda$ (Å)

$\log (I)$

50 5% contours

Experimental absorption = 68%
LILAC absorption = 70%

LILAC simulation

0 1 2

Time (ns)

No SSD, $I_{14} = 6.5$

Experimental spectrum

$\Delta \lambda$ (Å)

$\log (I)$

50 5% contours

Experimental absorption = 68%
LILAC absorption = 72%

LILAC simulation

0.3-THz SSD, $I_{14} = 7.2$

Red shift

Experimental spectrum

$\Delta \lambda$ (Å)

$\log (I)$

50 5% contours

Experimental absorption = 68%
LILAC absorption = 70%

LILAC simulation

0 1 2

Time (ns)

No SSD, $I_{14} = 6.5$

Experimental spectrum

$\Delta \lambda$ (Å)

$\log (I)$

50 5% contours

Experimental absorption = 68%
LILAC absorption = 72%

LILAC simulation

0 1 2

Time (ns)
**LILAC** also very well reproduced the scattered-light spectra for 0- and 0.3-THz SSD.

**0.3-THz SSD, $I_{14} = 7.2$**

Experimental spectrum

$\Delta \lambda (\AA)$

Red shift

$\log (I)$

Experimental absorption = 68%

**LILAC absorption = 70%**

**LILAC simulation**

$\Delta \lambda (\AA)$

$0$ $1$ $2$

Time (ns)

$-4$ $-2$ $0$

$50$ $50$ $50$ $50$

$50$ $50$ $50$ $50$

50 $5\%$ contours

**No SSD, $I_{14} = 6.5$**

Experimental spectrum

$\log (I)$

$3$ $2$

Experimental absorption = 68%

**LILAC absorption = 72%**

**LILAC simulation**

$0$ $1$ $2$

Time (ns)

$-4$ $-2$ $0$

$50$ $50$ $50$ $50$

$50$ $50$ $50$ $50$

50 $5\%$ contours
Experimental and simulated scattered-light spectra are very close for medium \((7 \times 10^{14})\)- and high \((10^{15})\)-irradiation intensities.

**Experimental absorption** = 62 \(\pm\) 3%

**LILAC absorption** = 63%

**LILAC simulation**

- **0.3-THz SSD,** \(I_{14} = 10.3\)
- **No SSD,** \(I_{14} = 10.1\)

**Experimental absorption** = 64%

**LILAC absorption** = 65%
Experimental and simulated scattered-light spectra are very close for medium \((7 \times 10^{14})\)- and high \((10^{15})\)-irradiation intensities.

\[ \text{Red shift} \]

\[ \Delta \lambda (\text{A}) \]

\[ \text{Experimental absorption} = 62 + 3\% \]

\[ \text{LILAC absorption} = 63\% \]

\[ \text{LILAC simulation} \]

\[ \text{Experimental absorption} = 64\% \]

\[ \text{LILAC absorption} = 65\% \]

\[ \text{LILAC simulation} \]
Scattered-light spectra, powers, and absorption depend very weakly on SSD bandwidth ($\approx 0.3$ THz) even at higher intensities.

- The spectral widths of scattered-light spectra are only slightly larger for 0.3-THz SSD compared 0 THz.
- Time-integrated absorption does not depend on SSD bandwidth.
- The scattered-light powers with and without SSD are basically identical.
CBET spectra are sensitive to density at the interaction region for high SSD bandwidths

**1-THz SSD, $I_{14} = 8$**
- 54926 H13
- 50 10% contours
- 864 μm (9.7-μm wall, 66-μm ice)
- CD target

**0.3-THz SSD, $I_{14} = 7.2$**
- 80807 H13
- 50 5% contours
- 877 μm (8-μm wall, 51-μm ice)
- CH target

**No SSD, $I_{14} = 6.5$**
- 80811 H13
- 50 5% contours
- 877 μm (8-μm wall, 51-μm ice)
- CH target

Standard OMEGA cryogenic implosions
1-THz SSD shows sensitivity of scattered light spectra to the density in the CBET interaction region.
The scattered-light powers and absorption are surprisingly independent of SSD bandwidth (0 versus 1 THz)

1-THz SSD, $I_{14} = 8$

1-THz SSD, $I_{14} = 8.1$

Experimental absorption = 71%

Experimental scattered light

Experimental absorption = 69%

SG4, 868 (33)-μm CH target, 17.1 kJ
For 1-THz SSD, the centroid of the scattered-light spectrum is shifted but the 5% contour is extremely well modeled by LILAC.
Summary/Conclusions

Scattered light powers and absorption are essentially unaffected by smoothing by spectral dispersion (SSD) bandwidth

- Scattered-light spectra are qualitatively affected by large SSD bandwidth (1 THz)
- Scattered-light spectra for $\leq 0.3$-THz SSD bandwidth are only minimally affected
- Hydrodynamic (LILAC) predictions for scattered-light powers and absorption are very close to experimental observations
- Predicted scattered-light spectra for $\leq 0.3$ THz are close to experimental observations
- For 1-THz SSD the measured spectral shifts indicate cross-beam energy transfer (CBET) occurs at higher densities without affecting scattered powers and absorption