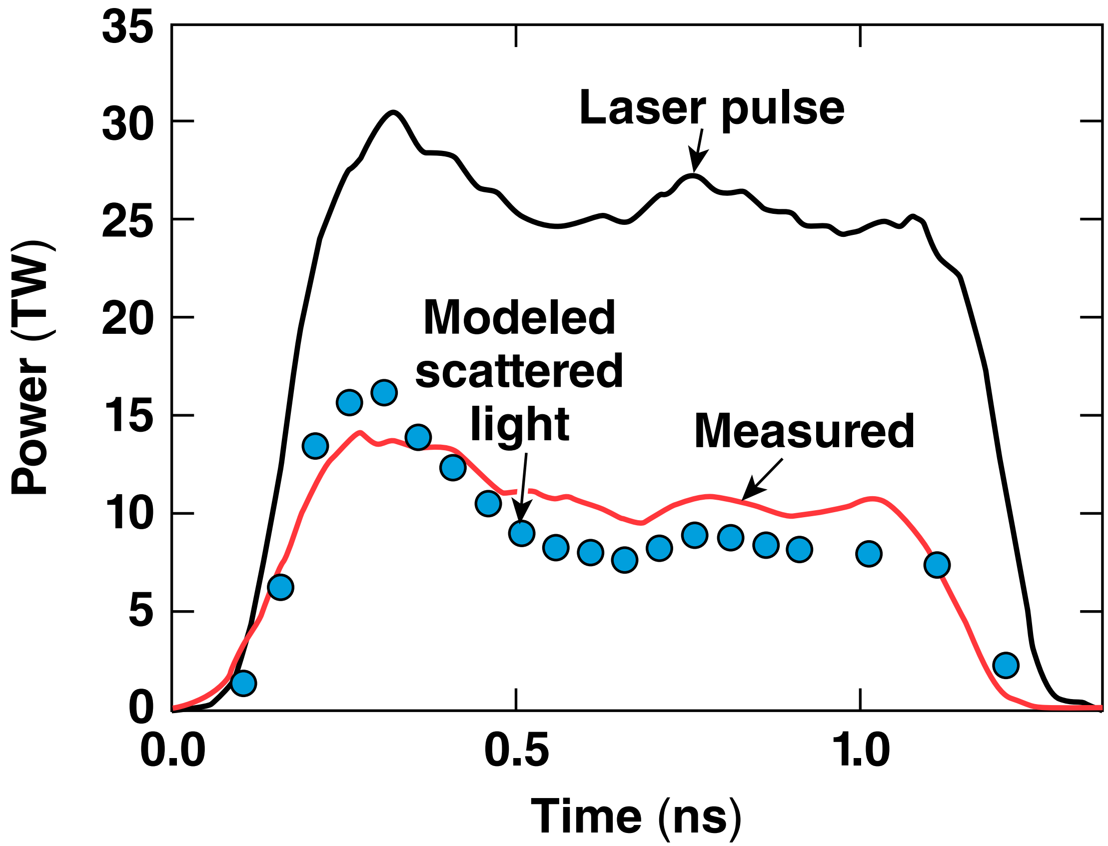
Cross-Beam Energy Transport in Direct-Drive-Implosion Experiments



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Summary

Observations and modeling of scattered-light spectra suggest cross-beam energy transfer during direct-drive implosions

- Without cross-beam energy transfer, hydrocode and ray-tracing predictions of the time-varying scattered light spectrum from OMEGA implosions show significant discrepancies with measurments.
- Including SBS cross-beam energy transfer improves the simulation of the observed scattered-light spectrum.
- Cross-beam energy-transfer modeling also reproduces the observed red shift in the SSD bandwidth for the scattered light.

Collaborators

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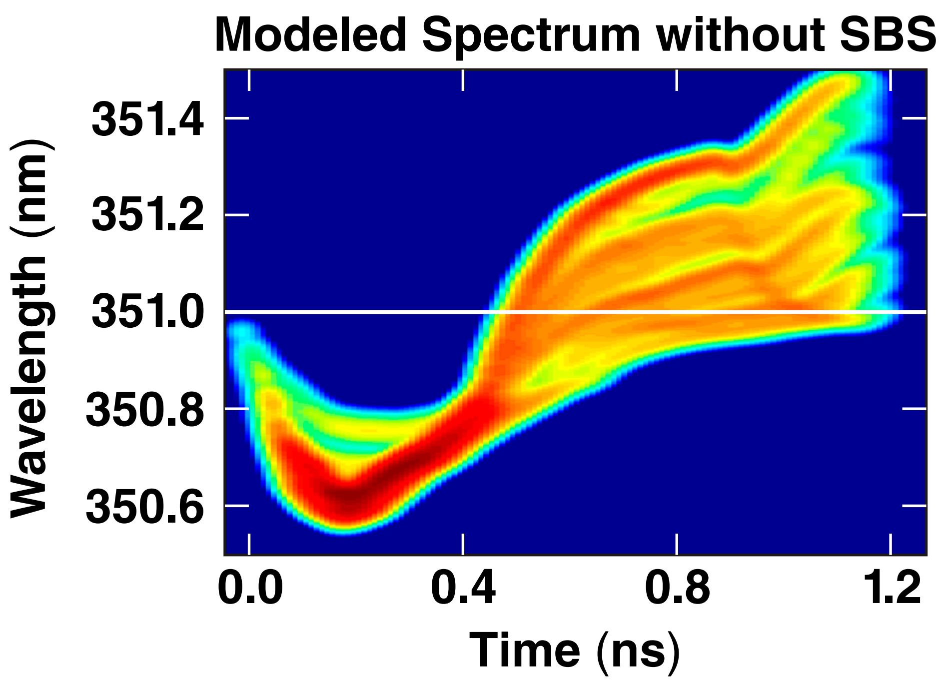
Modeled Spectra

Time-dependent scattered-laser-light spectra in the SBS range (351±1 nm) are modeled for OMEGA implosions



20-μm plastic shell
1-ns square pulse

- A combination of codes is used
  - *LILAC*[1]: 1-D hydrodynamic code predicts time-dependent implosion profiles
  - *SAGERAYS*[2]: Ray traces laser light through the corona and calculates spectral shift[3]
  - *MATLAB* code calculates total FABS spectrum collected from all 60 OMEGA beams

[1] J. A. Delettrez *et al*., Phys. Rev. A 36, 3926 (1987).
[2] R. S. Craxton and R. L. McCrory, J. Appl. Phys. 56, 108 (1984).
[3] T. Dewandre, J. R. Albritton, and E. A. Williams, Phys. Fluids 24, 528 (1981).

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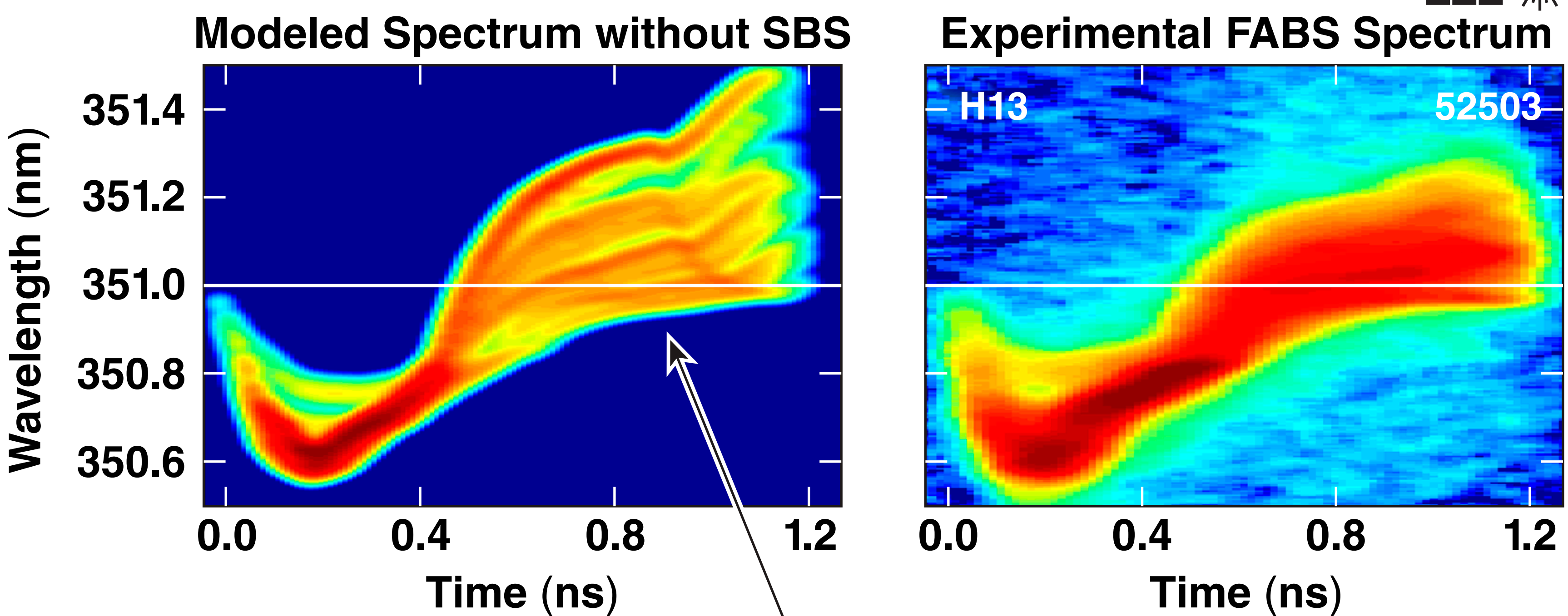
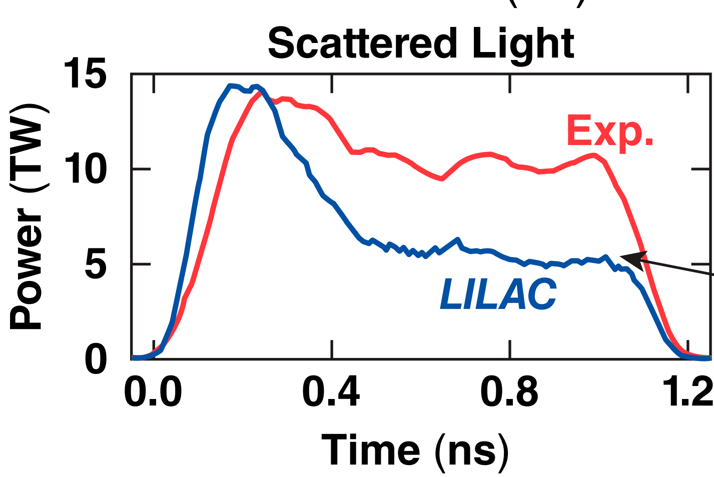
Scattered-light spectra modeled without cross-beam transfer show all the basic structures observed but differ in some important details





Tail spread too large and uppermost finger too intense

Total scattered light underpredicted (only 12% of total absorption)

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Cross-Beam Power Transfer

EM-seeded SBS cross-beam power transfer might cause some laser energy to "bypass" the high-absorption zone

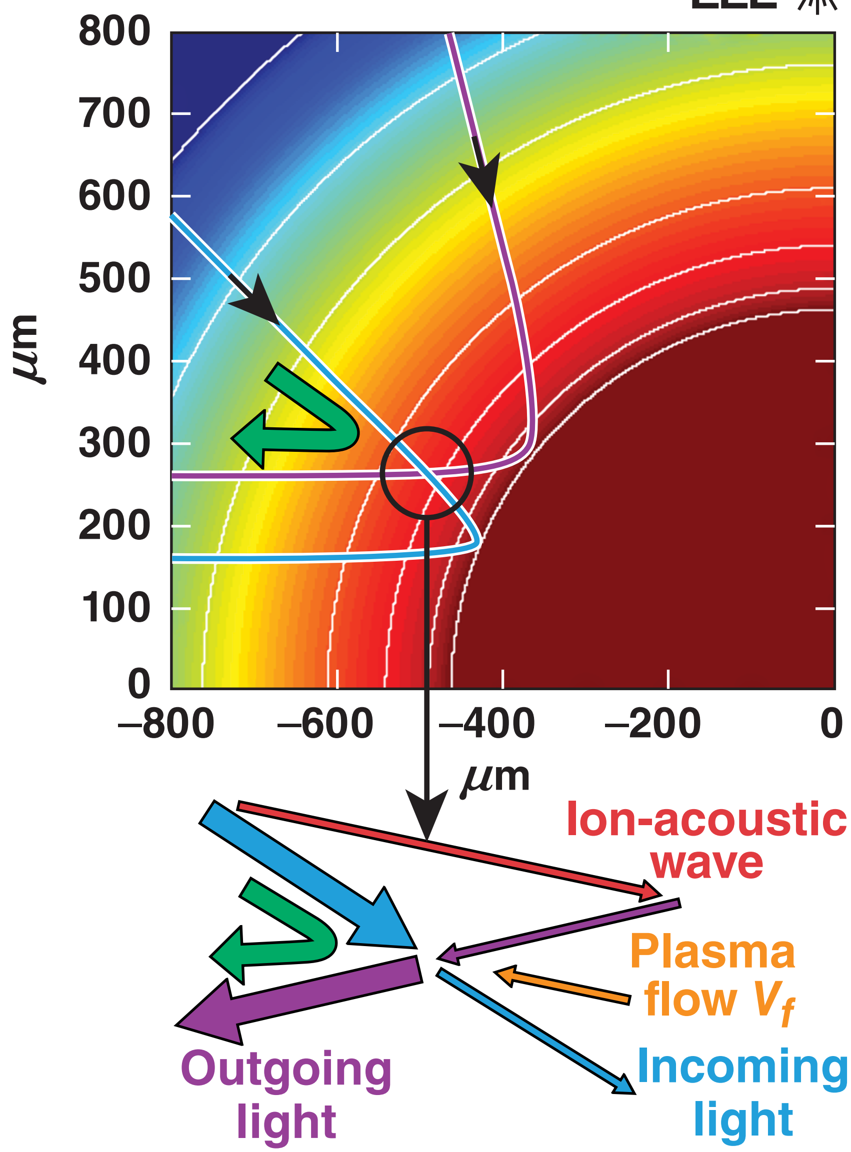
- Ion-acoustic wave (IAW) transfers energy from a "pump" EM wave to a "seed" EM wave

$$\omega_{\text{pump}} = \omega_{\text{seed}} + \omega_{\text{IAW}}$$

$$\vec{k}_{\text{pump}} = \vec{k}_{\text{seed}} + \vec{k}_{\text{IAW}}$$

$$0 = \pm c_s \left| k_{\text{IAW}} \right| + \vec{v}_f \cdot \vec{k}_{\text{IAW}} - \omega_{\text{IAW}}$$

- Light entering the plasma can transfer energy to light that is leaving the plasma



Because the EM seed amplitude is of the same order as the pump, very small gains of only a few percent could significantly affect the absorbed energy.

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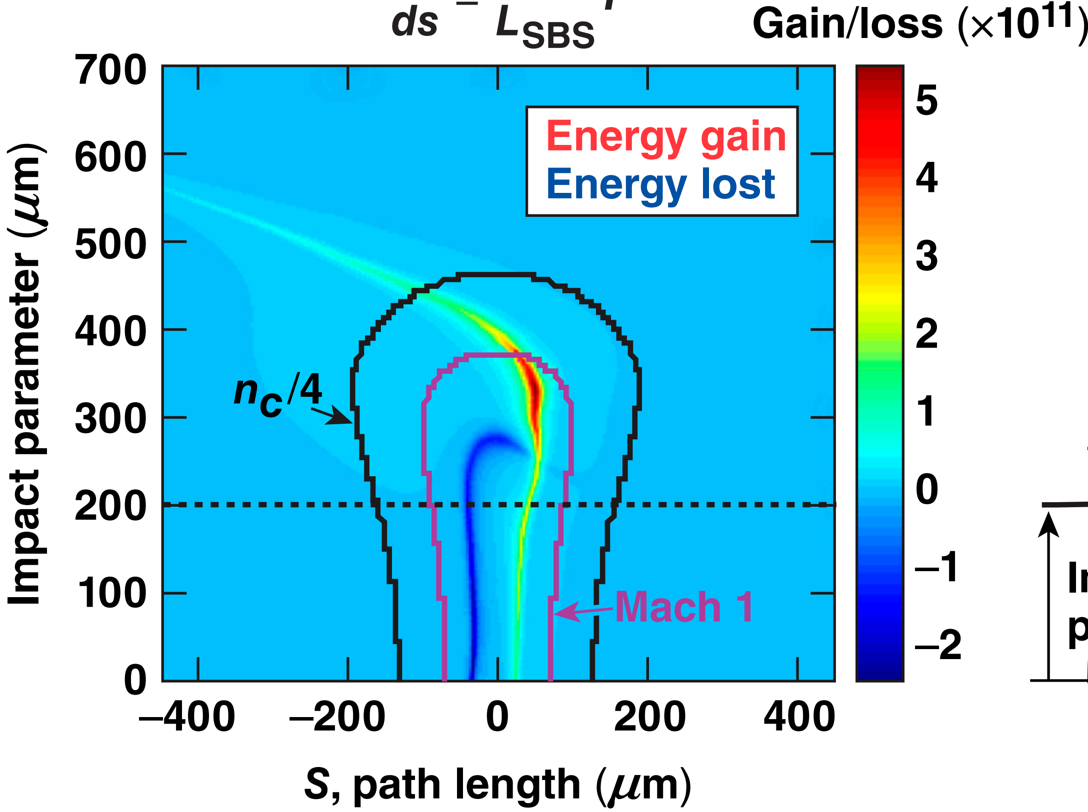
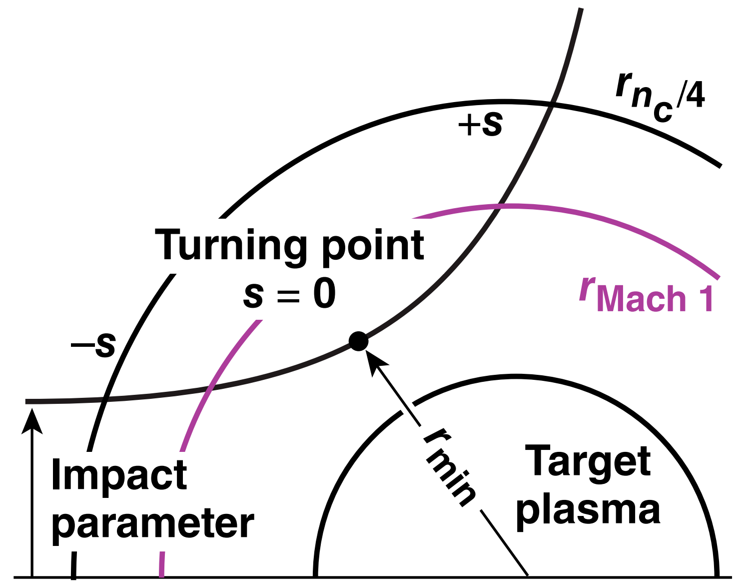
Beam crossings calculated from ray trace indicate that energy is typically lost by incoming beamlets

$$\frac{dI}{ds} = \frac{I}{L_{SBS}} P$$





Strength of the transfer is estimated using the spatial gain length* L_{SBS} for crossing planar waves and a measure** of how close the conditions are to resonance for SBS cross-beam transfer

The reference beam is at 40° for one set of beamlets from one beam crossing.

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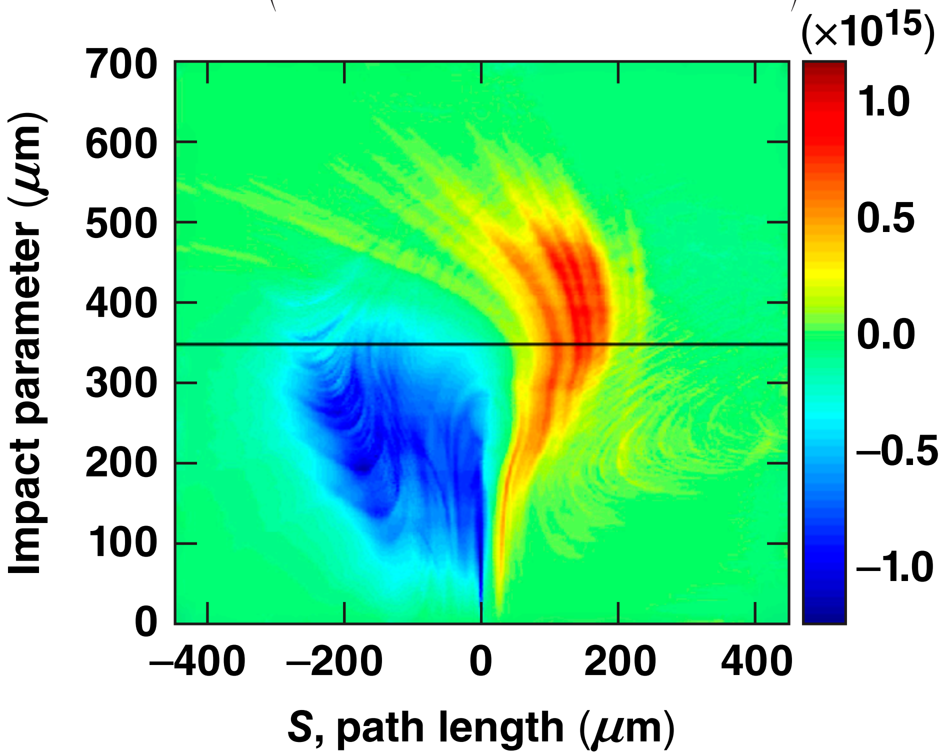
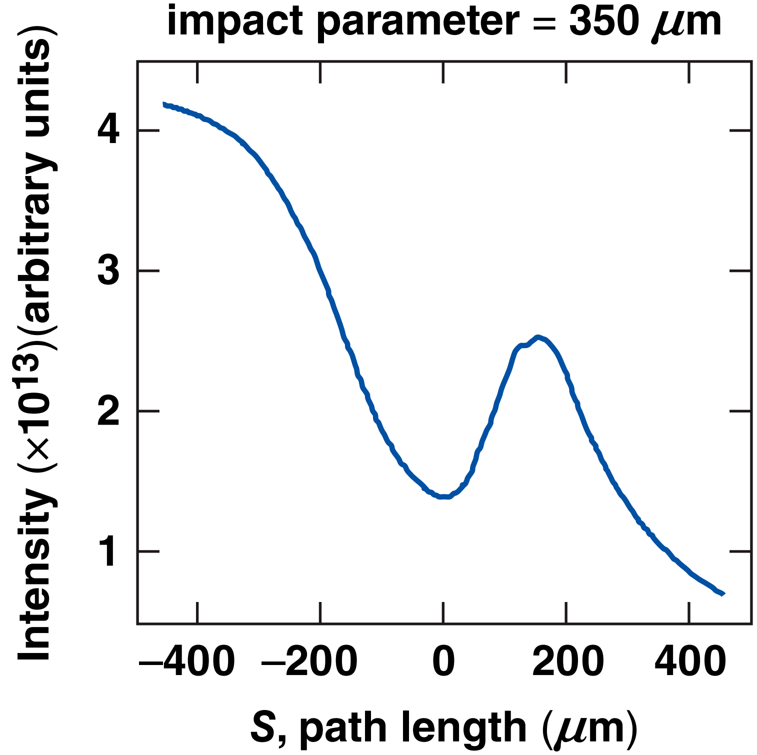
*J. F. Myatt *et al.*, Phys. Plasmas 11, 3394 (2004).
**C. J. Randall, J. R. Albritton, and J. J. Thomson, Phys. Fluids 24, 1474 (1981).

Calculating the energy lost/gained along each beamlet supports the transfer of energy out of beam center

$$d(IA) = -IA\left(\frac{1}{L_{\mathrm{abs}}} + \sum_{\substack{\mathrm{all}\\ \mathrm{beams}}} \sum_{\varphi} \frac{1}{L_{\mathrm{SBS}}} P\right) ds$$



Intensity along beamlet with impact parameter = 350 μm



Summed over all sets of beamlets from all beams crossing the reference beam

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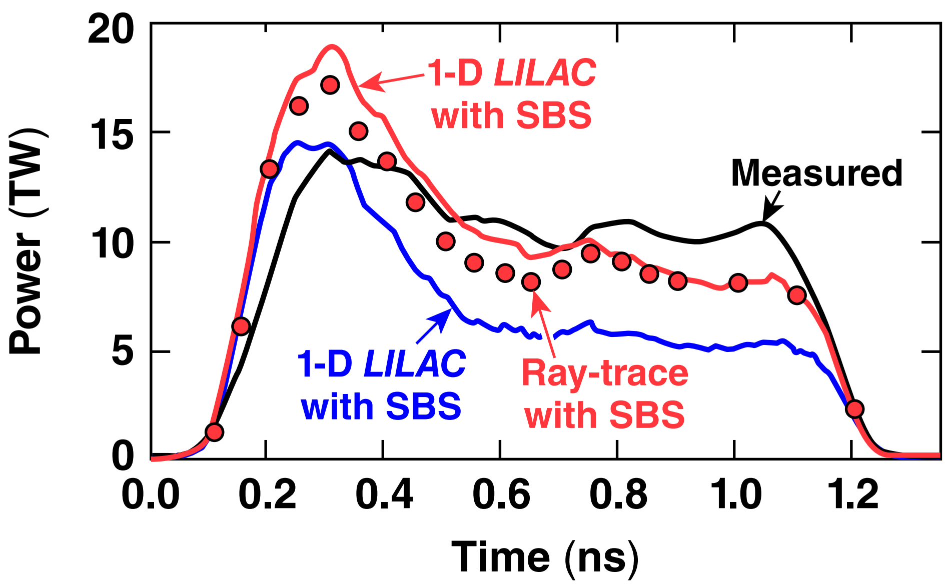
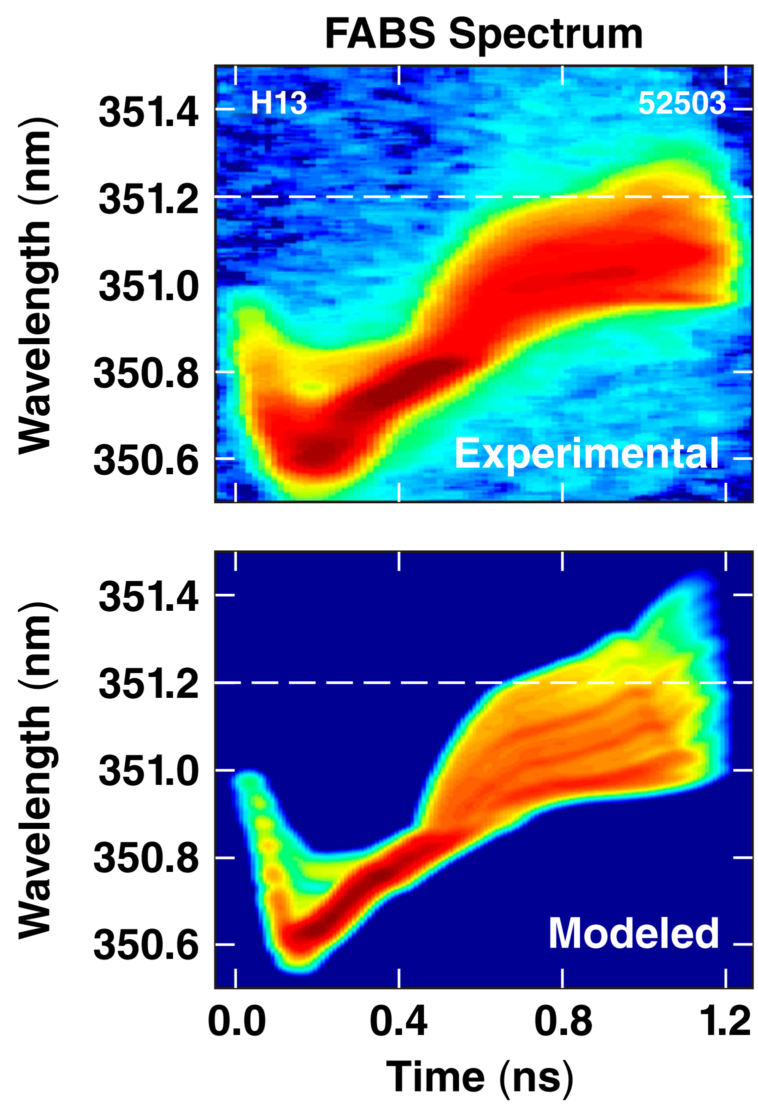
Cross-beam transfer scattered-light modeling improves the total scattered light and spectrum predictions





- Calculations using plasma profiles from *LILAC* with a 1-D model of cross-beam energy transport have more self-consistency

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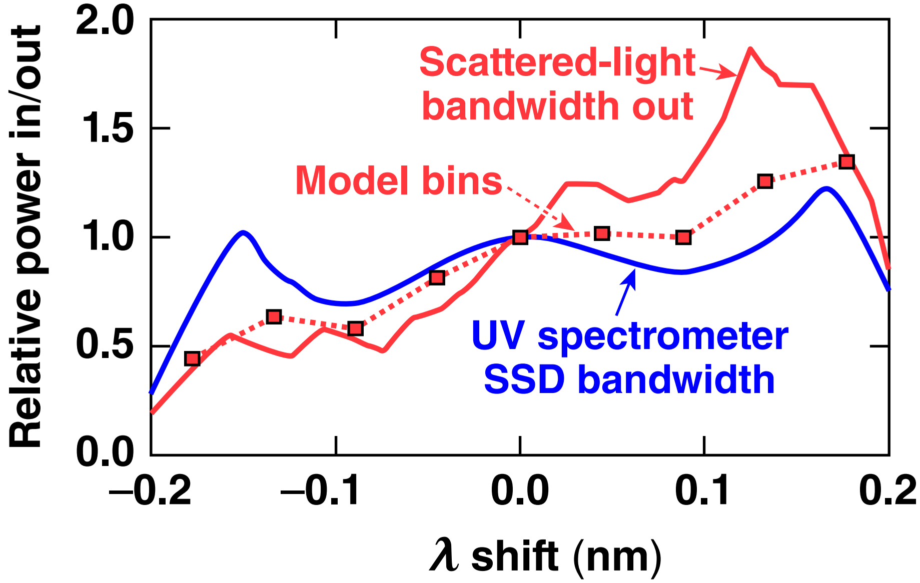
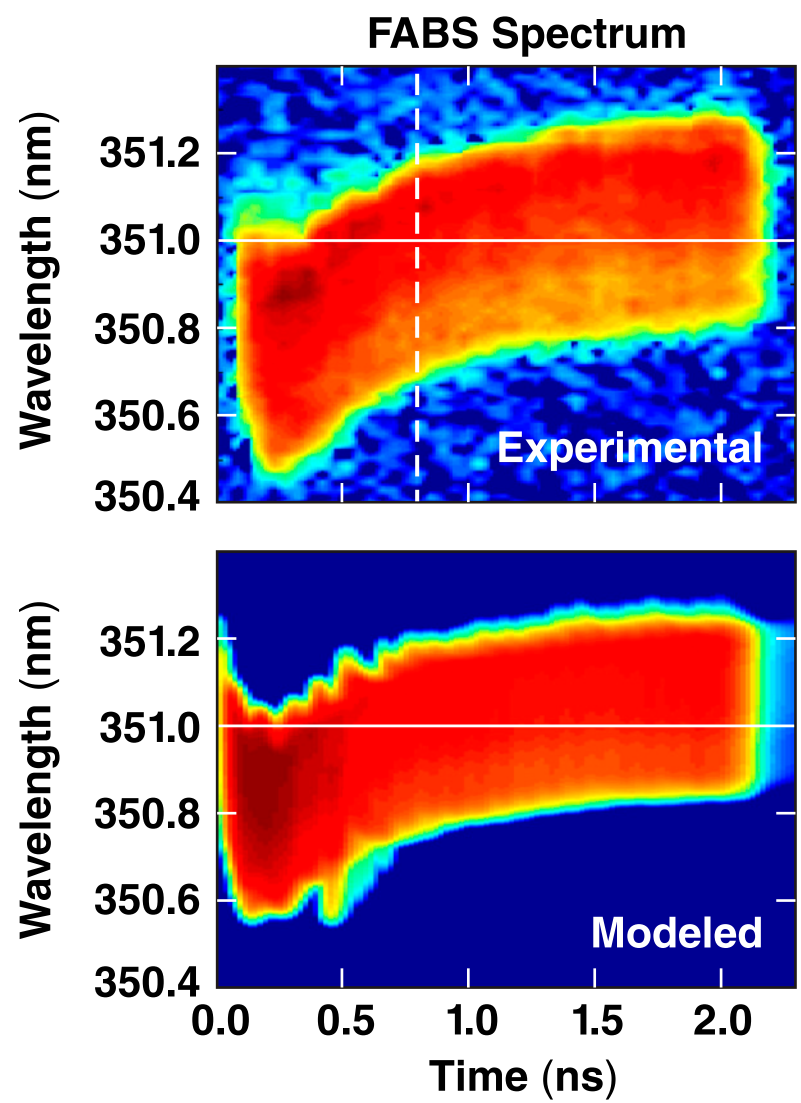
Cross-beam energy-transfer calculations predict the observed red-shift in bandwidth for scattered light





- For implosions with SSD, the scattered-light bandwidth is always strongly peaked on the red side
- When the cross-beam energy transfer is calculated independently for wavelength "bins" of the SSD bandwidth, a peak on the red side is predicted

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Summary/Conclusions

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See also I. V. Igumenshchev (JO5.00015) and A. Shvydky (UO5.00009).

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