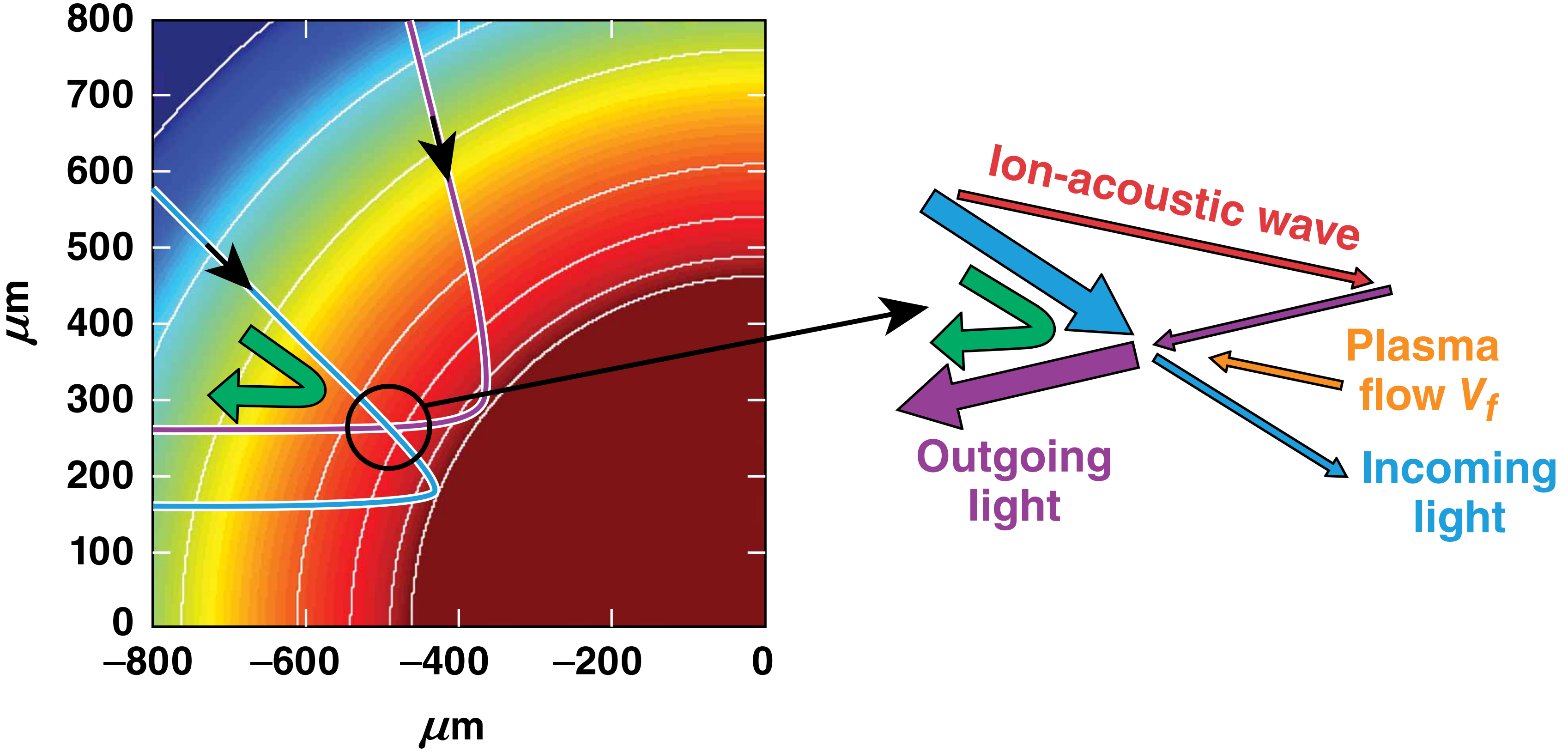
Time-Resolved Scattered-Light Spectroscopy in Direct-Drive-Implosion Experiments



D. H. Edgell
University of Rochester
Laboratory for Laser Energetics

39th Annual Anomalous Absorption Conference
Bodega Bay, CA
14–19 June 2009

Summary

Scattered-light spectrum simulations indicate that anomalous absorption affects the latter part of implosions

UR LLE

- Time-dependent scattered-laser-light spectra in the SBS range (351±1 nm) are modeled by a combination of hydrodynamic and ray-tracing codes
- Most features observed in the scattered-light spectra are well reproduced by the modeling
- The largest discrepancy in the modeling suggests that absorption is over-estimated in the later part of the pulse, but scaling the total absorption to match observations still does not accurately reproduce the spectra
- Cross-beam transfer of energy out of the beam-profile center might be the physical process behind the discrepancy

Collaborators

W. Seka

V. N. Goncharov

I. V. Igumenshchev

R. S. Craxton

J. A. Delettrez

J. F. Myatt

A. V. Maximov

R. W. Short

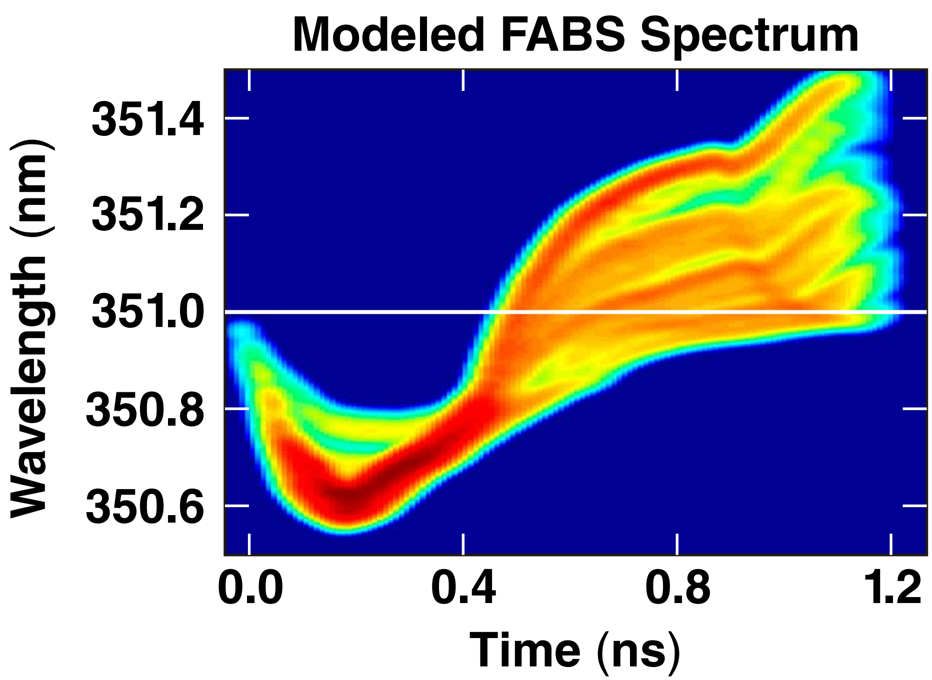
R. E. Bahr

University of Rochester
Laboratory for Laser Energetics

Modeled Spectra

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

UR LLE



20-μm plastic shell
1-ns square pulse

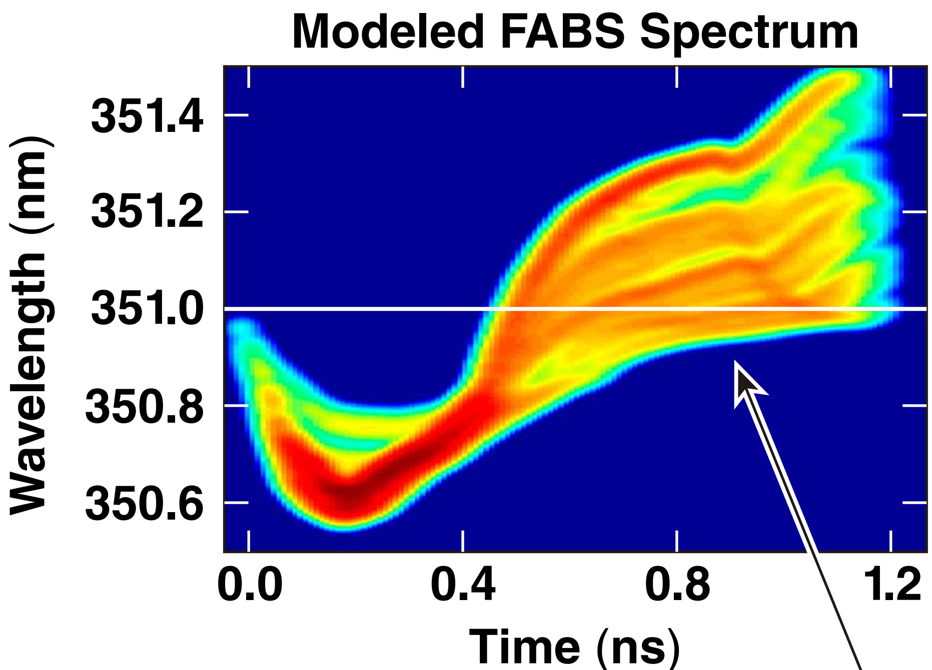
- A combination of codes is used
  - *LILAC*[1]: 1-D hydrodynamic code predicts time-dependent implosion profiles
  - *SAGERAYS*[2]: Ray traces laser light through the corona and calculates spectral shift[3]
  - *MATLAB* code calculates total spectrum collected from all 60 OMEGA beams

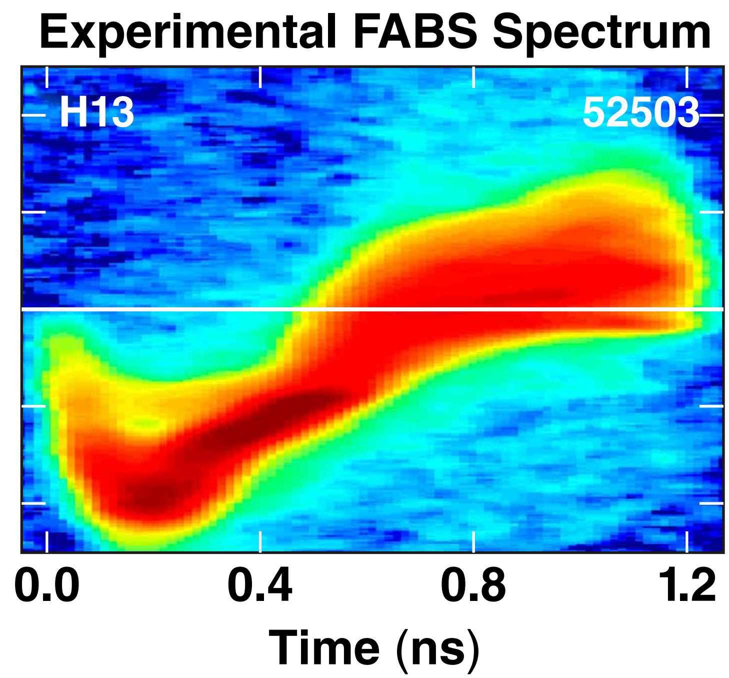
---

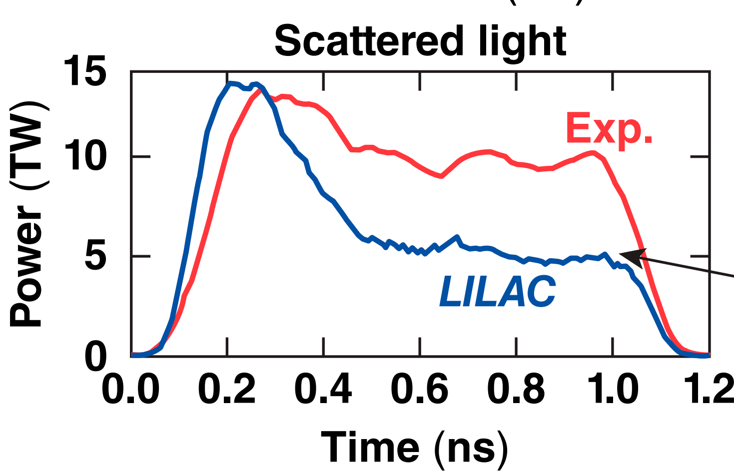
[1]J. A. Delettrez *et al*., Phys. Rev. A 36, 3926 (1987).
[2]R. S. Craxton and R. L. McCrory, J. Appl. Phys. 56, 108 (1984).
[3]T. Dewandre, J. R. Albritton, and E. A. Williams, Phys. Fluids 24, 528 (1981).

E17992

Modeled spectra show all the basic structures of the experimental spectra but differ in some details





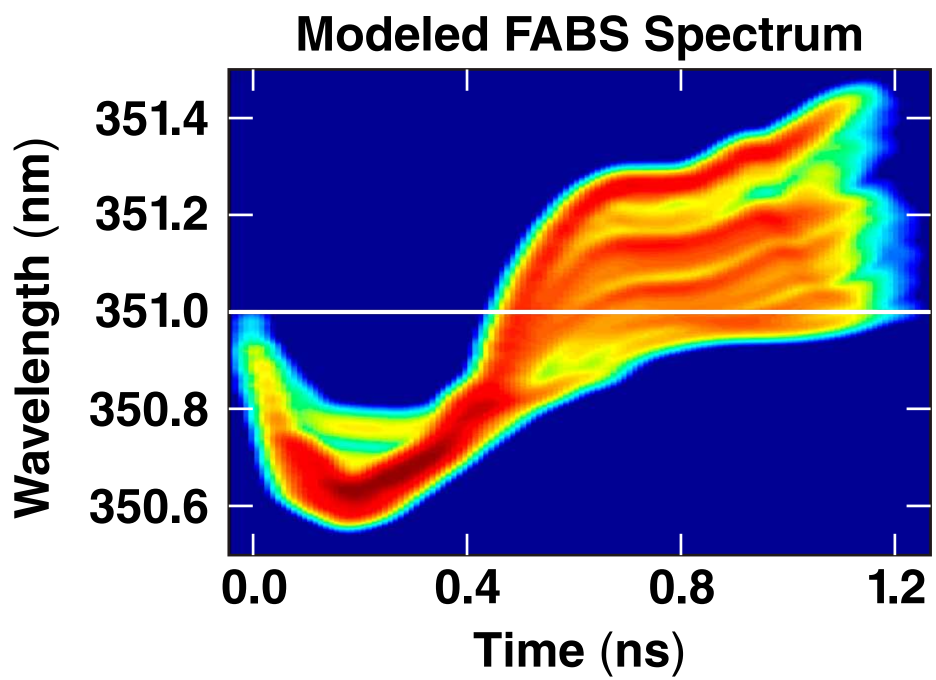


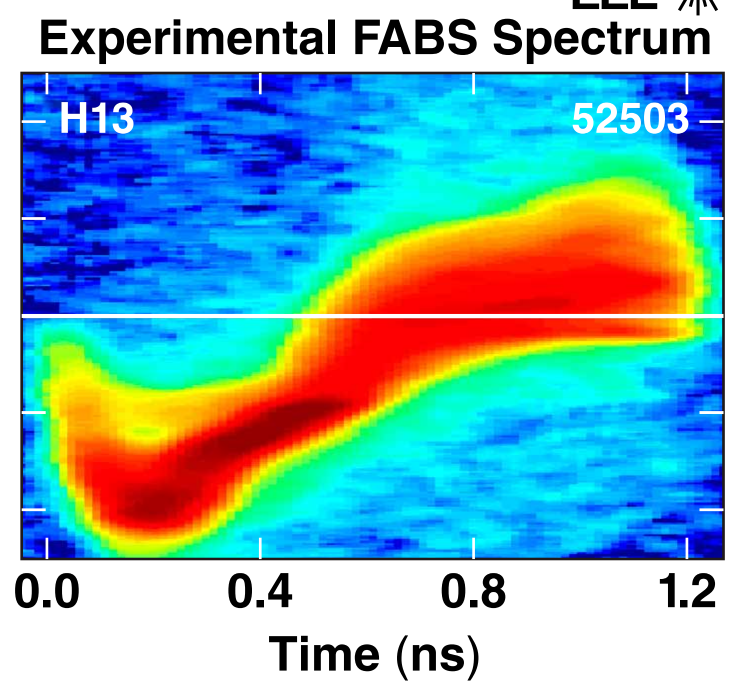
Tail spread too large and uppermost finger too intense

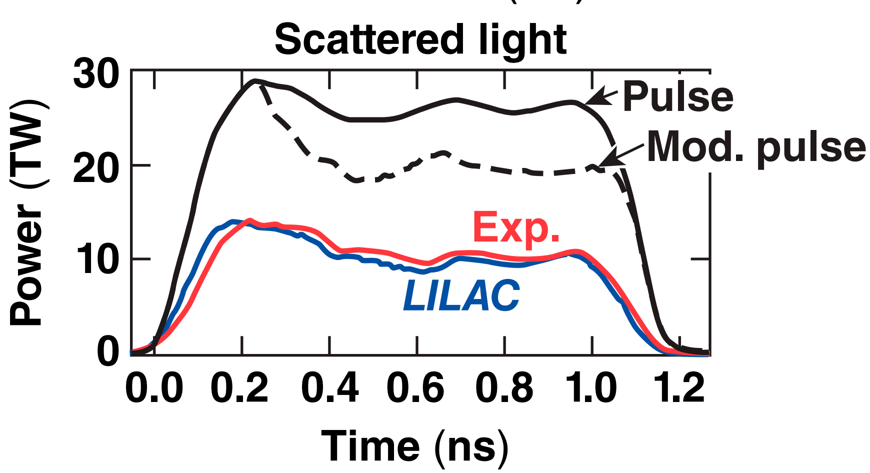
Total scattered light underpredicted (only 12% of total absorption)

E17329d

Modeling with the pulse power scaled to reproduce the observed time-dependent absorption does not significantly improve the spectral shift predictions







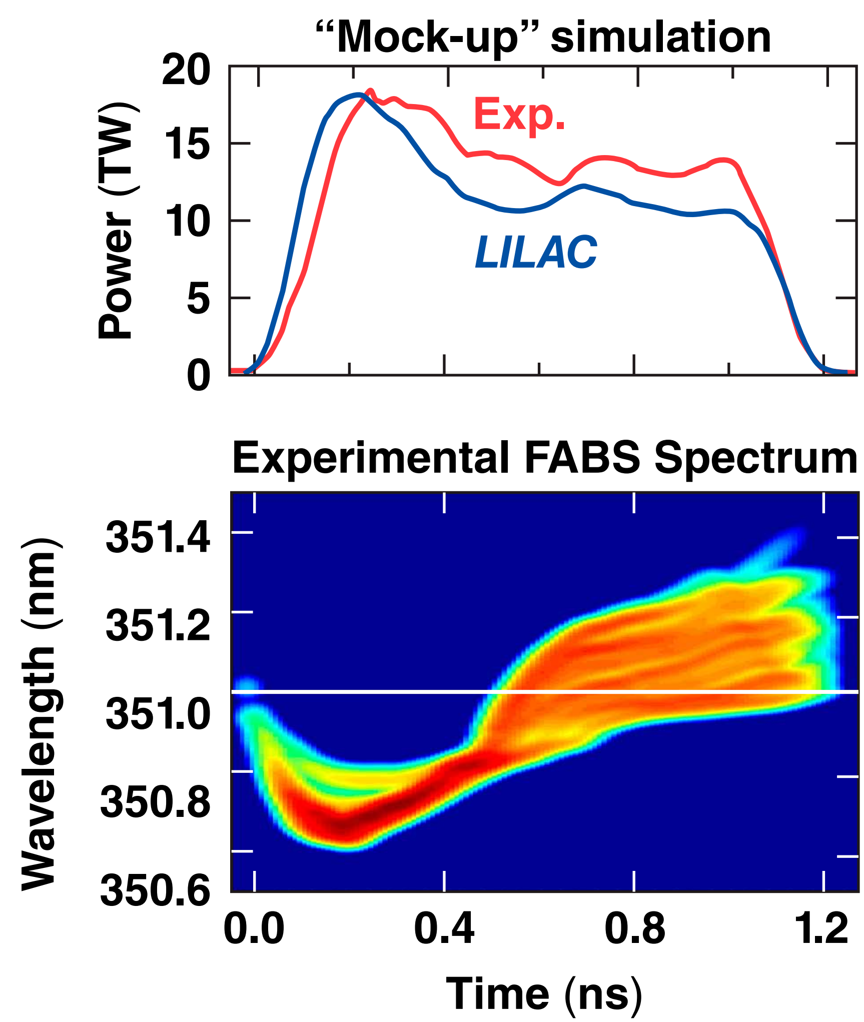
Where the energy is absorbed seems important, not just how much is absorbed.

E17995

Cross-beam transfer of energy from the beam profile center toward the profile edge might be consistent with the observations

UR LLE

- Removes energy from rays closest to center of beam profile that penetrate furthest towards the critical surface and are responsible for the uppermost finger of the spectrum tail
- Redistributes that energy to rays farther out in the beam profile where absorption is less
- Should result is a spectrum that better matches observations
  - – removes energy from the uppermost finger
  - – decreases total absorption/ increases total scattered energy



E17993

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

UR LLE

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

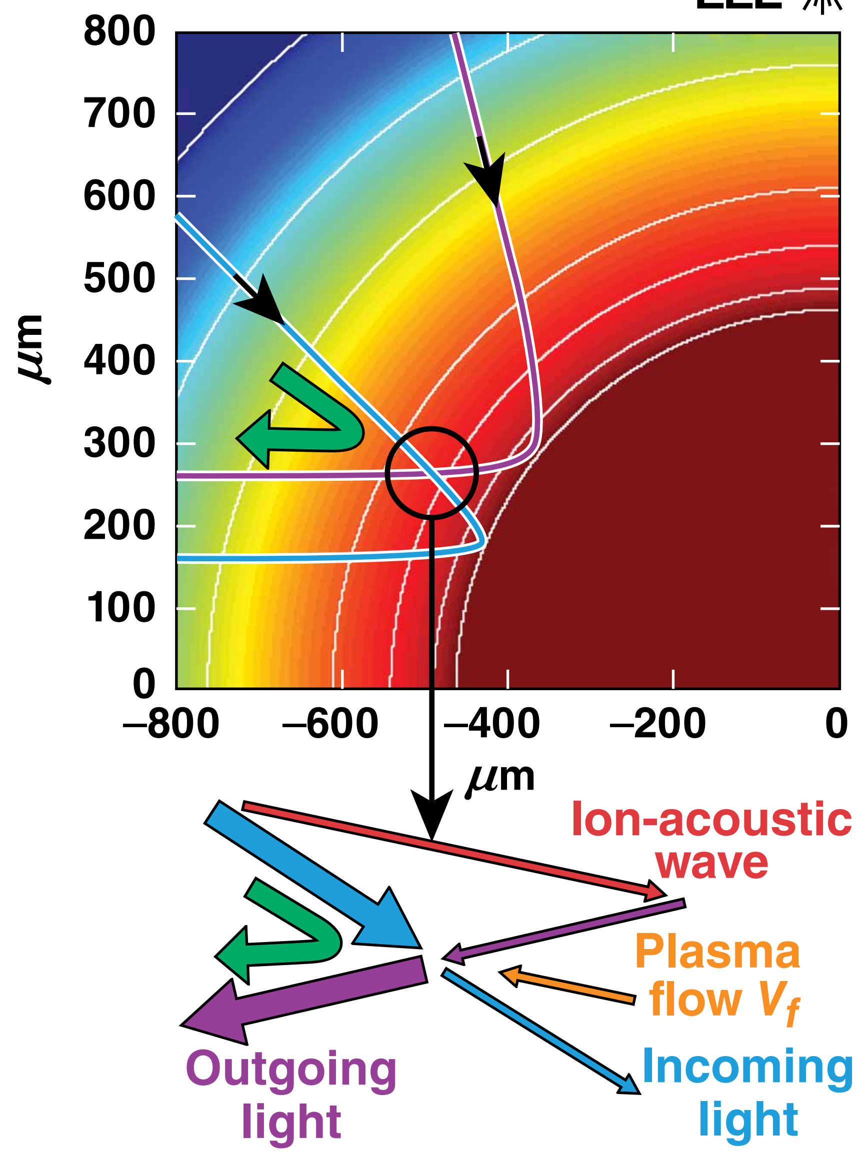
$$\omega_{\text{pump}} = \omega_{\text{seed}} + \omega_{\text{IAW}}$$

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

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

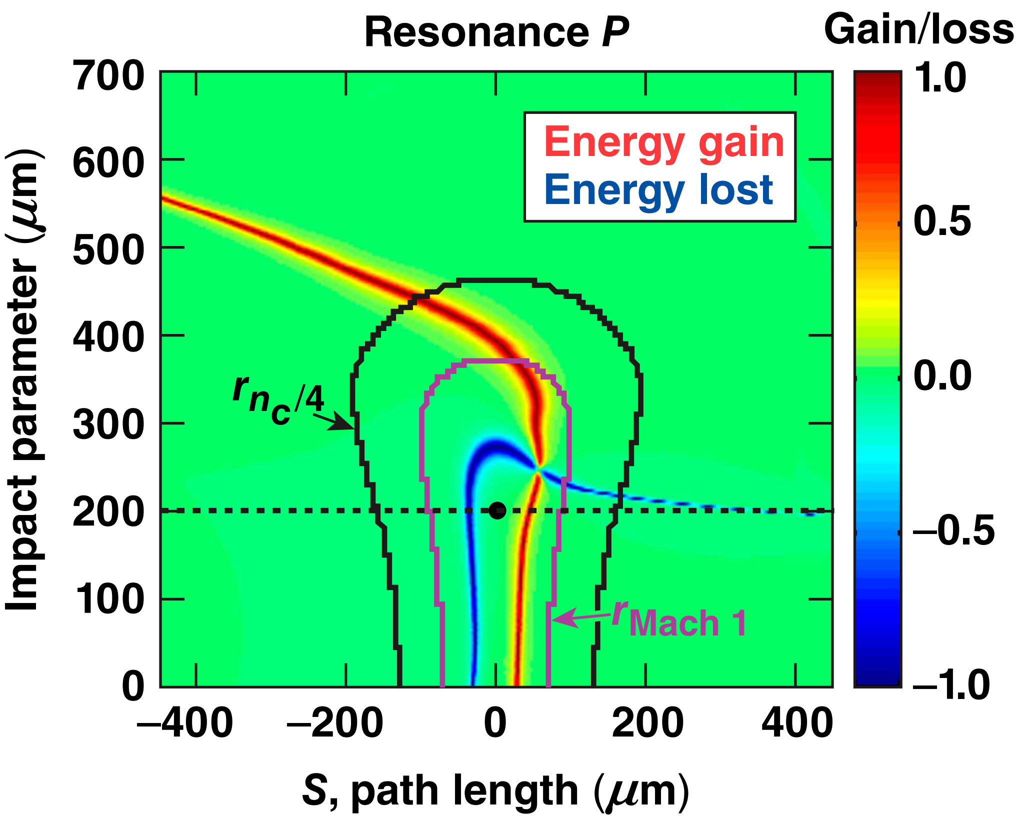
- Light entering the plasma can transfer energy to light that is leaving the plasma so that some laser energy "bypasses" the high-absorption region, reducing the total absorbed power

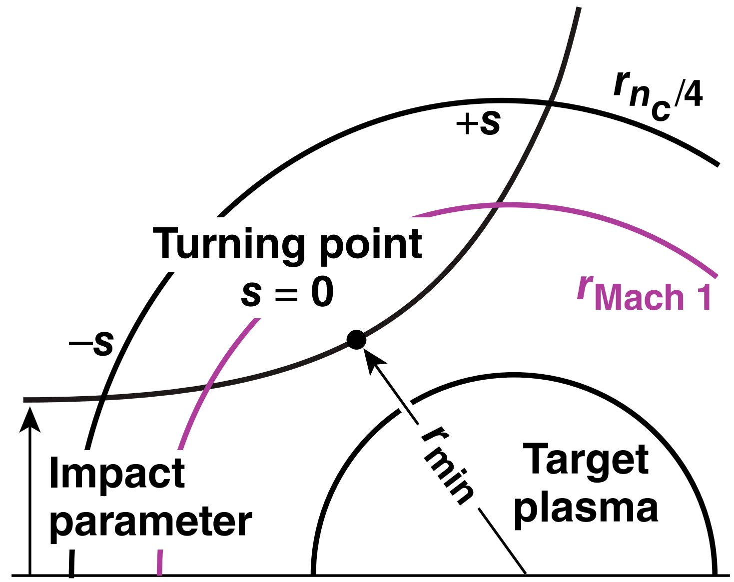
Because the EM seed amplitude is of the same order as the pump, very small gains of only a few percent could significantly affect the absorbed energy.



E17994

Beamlet crossings calculated from ray-trace and OMEGA beam geometry indicate that energy is typically lost by incoming beamlets





Resonance function* (*P*) is a measure of how close the conditions are to resonance for SBS cross-beam transfer

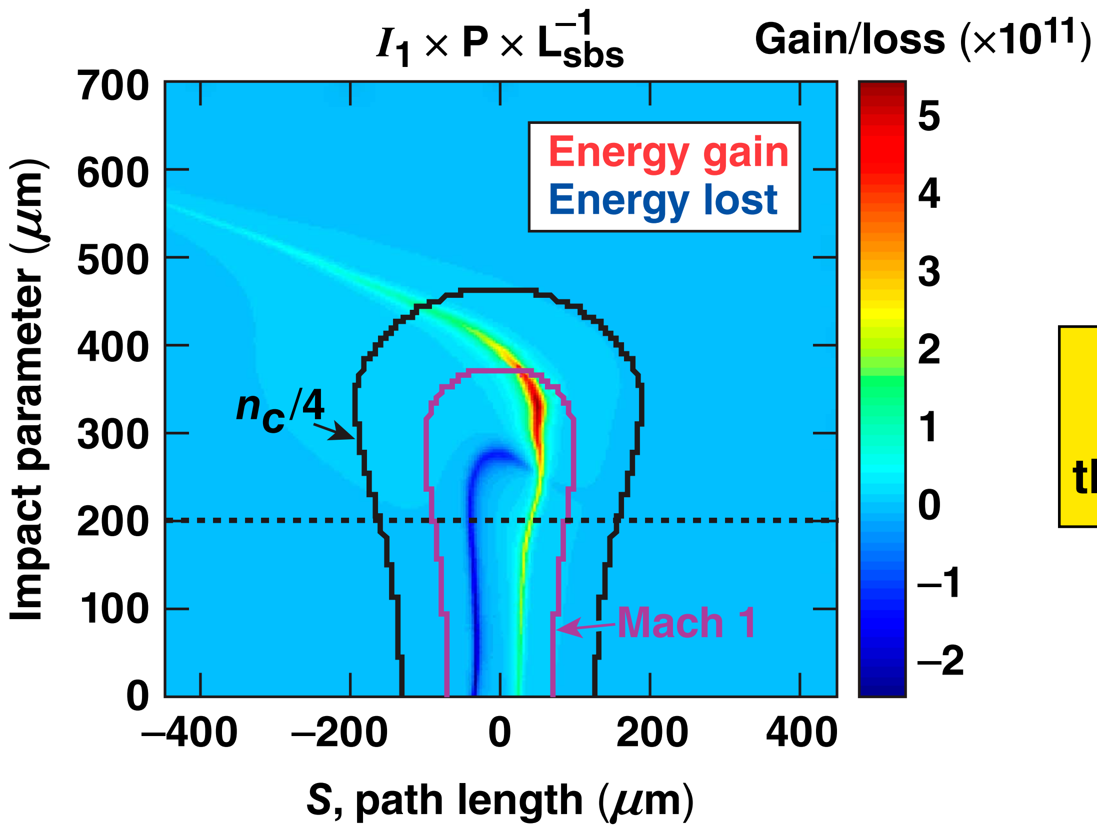
$$0 = \pm c_s |k_{\text{IAW}}| + \vec{v}_f \cdot \vec{k}_{\text{IAW}} - \omega_{\text{IAW}}$$

For one set of beamlets from one beam crossing the reference beam is at 40°

E17999

*C. J. Randall, J. R. Albritton, and J. J. Thomson, Phys. Fluids 24, 1474 (1981).

The strength of the transfer is estimated using the spatial gain length* L_{SBS} for crossing planar waves



For **one set of beamlets** from **one beam** crossing, the reference beam is at 40°

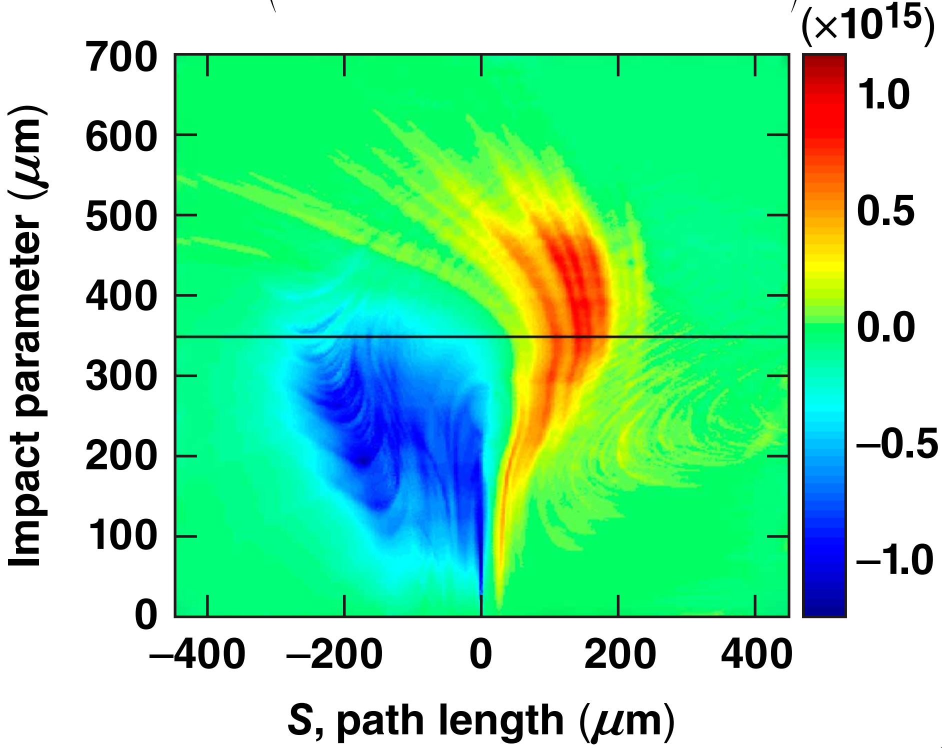
$$L_{SBS}^{-1} = 2.8 \times 10^{-2} \frac{1}{\nu_i \lambda_{0,\mu m}} \frac{n_e/n_c}{\sqrt{1 - n_e/n_c}} \frac{I_{14} \lambda_{0,\mu m}^2}{T_{e,\text{keV}} \left(1 + 3T_i/ZT_e\right)} P(\eta) \left(\mu m^{-1}\right)$$

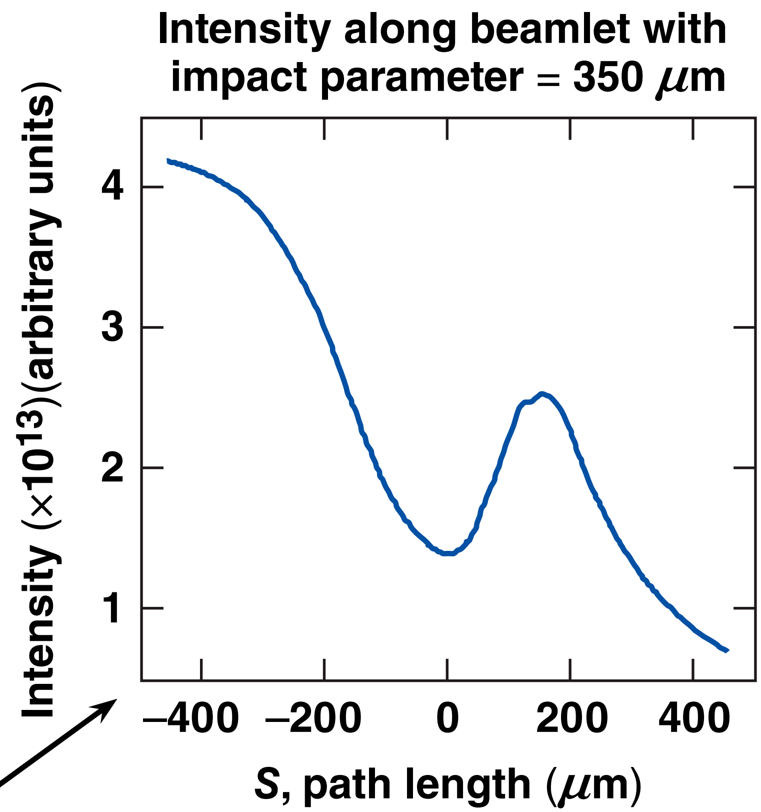
E17996

*J. F. Myatt *et al.*, Phys. Plasmas 11, 3394 (2004).

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

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



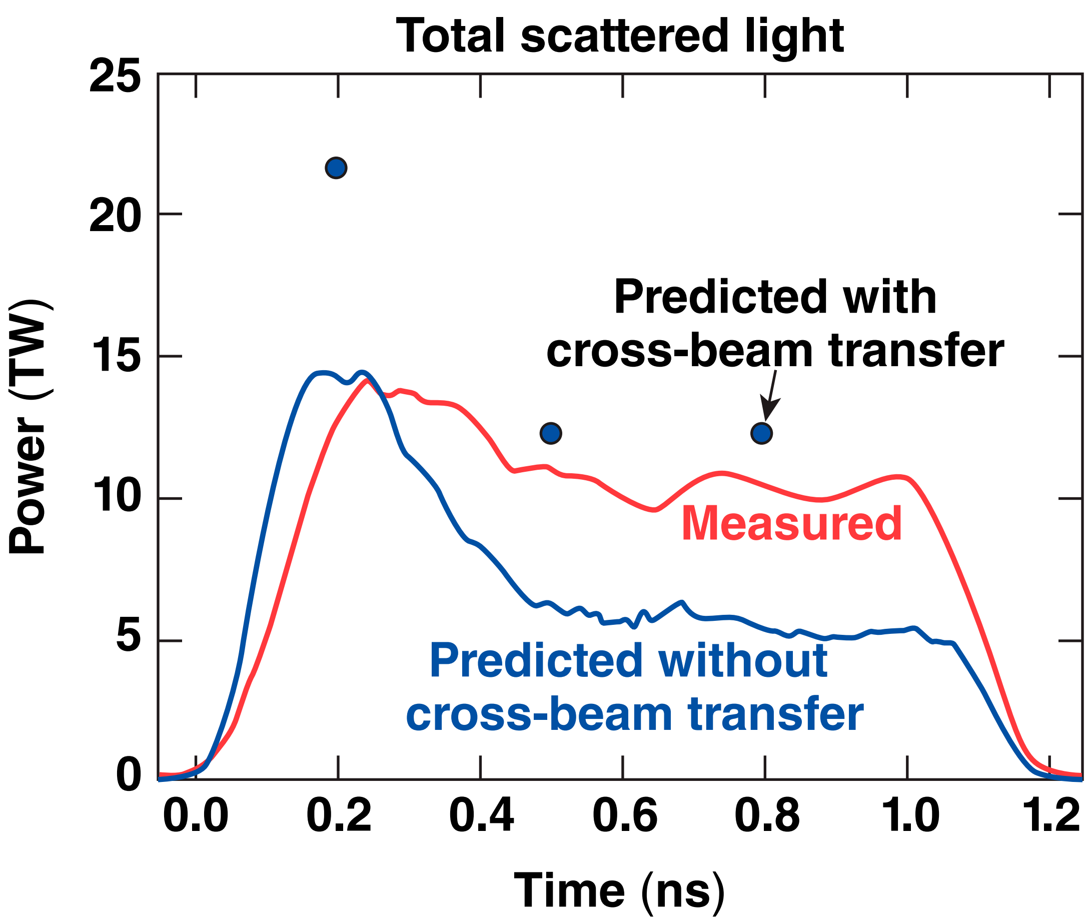


The rate of change in intensity caused by cross-beam transfer and absorption can be integrated along each path to determine the intensity

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

E17997

Cross-beam transfer scattered-light modeling improves the match to experimental data later in the implosion



- Early in the implosion modeling now shows too much scattered light
- Integrating cross-beam transfer into the hydrocode may improve the agreement

E17998

Summary/Conclusions

Scattered-light spectrum simulations indicate that anomalous absorption affects the latter part of implosions

UR LLE

- Time-dependent scattered-laser-light spectra in the SBS range (351±1 nm) are modeled by a combination of hydrodynamic and ray-tracing codes
- Most features observed in the scattered-light spectra are well reproduced by the modeling
- The largest discrepancy in the modeling suggests that absorption is over-estimated in the later part of the pulse, but scaling the total absorption to match observations still does not accurately reproduce the spectra
- Cross-beam transfer of energy out of the beam-profile center might be the physical process behind the discrepancy