Precision Scattered Laser Light Spectroscopy in Direct-Drive Implosions

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Summary

Scattered-light simulations may be reconciled with experiments by cross-beam energy transfer out of the central portion of the beam profile.

- Time-dependent scattered-laser-light spectra are modeled by a combination of hydrodynamic and ray-tracing codes.
- Analysis of the spectra indicates that the red shift of the scattered-light fan tail is poorly modeled.
  - especially for scattered light originating from the central portion of the beam profile.
- Modeled spectra with simulated cross-beam energy transfer out of the beam profile center produce a much better match to the experimental scattered-light spectra.
Collaborators

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Modeling Spectra

Time-dependent scattered-light spectra are modeled for OMEGA implosions

- **LILAC**: 1-D hydrodynamic code predicts time-dependent plasma profiles using Goncharov nonlocal electron-heat transport model\(^1\)

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- **SAGERAYS**: Ray traces 351-nm-drive laser light through plasma and calculates spectral shift along each path

\[
\Delta \omega = -\omega_0 \frac{\partial \tau_f}{\partial t} = \frac{\omega_0}{2c} \int \left(1 - \frac{n_e}{n_c}\right)^{-1/2} \frac{\partial}{\partial t} \left(\frac{n_e}{n_c}\right) ds
\]

\(\tau_f\) = time of flight of light along ray

\(n_e\) = plasma density

\(n_c\) = plasma critical density

\(\omega_0\) = laser-light angular frequency

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\]

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- **MATLAB 3-D code** calculates total spectrum collected by FABS from all 60 beams

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Modeled scattered-light spectra show a detailed structure with both blue- and red-shifted components.

- Sharp initial blue shifts due to plasma production as laser pulse rises

Modeled FABS spectrum

Critical surface

40-μm plastic shell
Modeled scattered-light spectra show a detailed structure with both blue- and red-shifted components.

- Red-shifted “fan-tail” caused by compression of target
- Fan tail “fingers” are from beams at different angles with respect to spectrometer
Modeled spectra show all the basic structures of the experimental spectra but differ in some details.

Total scattered light underpredicted (only 12% difference in total absorption)

20-μm plastic shell
1-ns square pulse
Modeled spectra show all the basic structures of the experimental spectra but differ in some details.

- Modeled FABS Spectrum
- Experimental FABS Spectrum

Scattered light
- Initial blue shift well matched

20-μm plastic shell
- 1-ns square pulse
Modeled spectra show all the basic structures of the experimental spectra but differ in some details.

- Modeled FABS Spectrum
- Experimental FABS Spectrum
- Scattered light
- Fan-tail spread too large
- 20-μm plastic shell
- 1-ns square pulse
Modeled spectra show all the basic structures of the experimental spectra but differ in some details.

Most red-shifted “finger” more intense

Beams on the side closest to the detector all show similar large shifts
The discrepancy between modeling and experiment is not simply an overprediction of absorption

- Global scaling of the pulse energy to match observed total absorption does not significantly improve the spectral-shift predictions
- The predicted bang times are typically within 50 ps of the experimental value, suggesting the overall drive is fairly well modeled
- The experimental lack of an intense red-most beam finger suggests that absorption may be underpredicted for this finger
- Altering the profile of the beam to shift energy out of the beam center may provide reconciliation with experiments.
EM-seeded SBS cross-beam power transfer might significantly alter the absorption profile

- Light entering the plasma can transfer energy to crossing light that is leaving the plasma via an ion acoustic wave.
- Laser-pulse energy from one part of the beam profile may be transferred to another, “bypassing” the highest absorption region (near the turning point).
Initial calculations support cross-beam energy transfer out of the beam profile center.
“Mock-up” simulation of energy transfer out of the beam center greatly reduces the discrepancy.

- Energy turned off in LILAC for central 150 \( \mu m \) of beam profile
- Energy redistributed to rest of spectrum in scattered light simulation

Incorporating a self-consistent cross-beam power-transfer model into LILAC is necessary for complete simulations.
Scattered-light simulations may be reconciled with experiments by reduced absorption in the central portion of the beam profile

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