Modeling Laser–Plasma Interaction Physics Under Direct-Drive Inertial Confinement Fusion Conditions

J. Myatt, A. Maximov, and R. W. Short
Laboratory for Laser Energetics
University of Rochester

UV critical surface

Laser

Spot size ~ 1 mm

140 λ₀

1000 λ₀

Z = L₀

E

E

E

E

Z = 0

44th Annual Meeting of the American Physical Society
Division of Plasma Physics
Orlando, FL
11–15 November 2002
Summary/Conclusions

OMEGA direct-drive LPI experiments have been successfully modeled using pF3D

- Large-scale simulations relevant to direct-drive OMEGA LPI experiments using pF3D (Berger, Still – LLNL)
  - Simulated SBS backscatter compares favorably in two types of long-scale-length OMEGA experiments.
  - Hydrodynamic evolution of plasma profile is shown to be important.
  - Position and temporal behavior of blue spectral feature are determined by a uniform “shelf” in underdense corona.
- OMEGA experiments do not match exactly the NIF conditions.
  - NIF expansion velocities are lower and more uniform.
  - Simulations are currently underway.
Outline

• Simulations have been made with pF3D.

• Simulations include backward SBS.
  – Simulations compared with experiment.
  – Target hydrodynamics

• Extrapolation to NIF targets
Large-scale pF3D simulations of OMEGA direct-drive LPI experiments have been carried out with the correct inhomogeneous plasma profiles.

- We have carried out two types of simulations:
  - 3-D “pencil” with no backward SBS (shown to right)
  - 2-D slice with backward SBS (no variation in y direction)

- Plasma hydrodynamic variables are initialized using data from SAGE simulations.
A “shelf” in the plasma expansion velocity is a common feature of all direct-drive experiments.

- Ablation due to the rising pulse of the interaction beam creates a shelf that propagates down the gradient with time.
- Most prominent in multiple beam irradiation.
Blue spectral feature in the backscatter is a result of SBS in the underdense corona and is correctly reproduced in pF3D simulations.

- The red feature is seeded by reflection and originates from near the critical surface.
- Here we model the blue feature only.
The level and temporal dependence of the simulated SBS reflectivity are consistent with experiment

- Experiment with multiple interaction beams displays an early “quenching” of SBS signal
- During the later part of the pulse the reflectivity is less than a few percent for all simulated intensities.
- The reflectivity is not far from linear gain estimates due to strong gradients.

![Graph showing power reflectivity vs. time with different intensities labeled: I = 9 \times 10^{14} \text{ W/cm}^{-2}, I = 8 \times 10^{14} \text{ W/cm}^{-2}, I = 6 \times 10^{14} \text{ W/cm}^{-2}, I = 4 \times 10^{14} \text{ W/cm}^{-2}. The x-axis represents time in ps ranging from 0 to 1500, and the y-axis represents power reflectivity on a logarithmic scale from 10^{-5} to 10^0.]
Backward SBS occurs primarily in the shelf of ablated material caused by the rising interaction beam

- Due to the nearly monotonic expansion velocity profile, the location of Brillouin IAW determines the spectral shift of the backscattered EM wave.

- This is consistent with the observed experimental blue-shift.
The shelf of uniform expansion velocity propagates down the gradient towards lower densities.

- The gain for SBS depends upon plasma density, and as a result it falls rapidly in time.

![Graphs showing plasma density and expansion velocity over time](image)
Blue spectral feature in the backscatter is a result of SBS in the underdense corona and is correctly reproduced in pF3D simulations.

- The difference in the blue spectral feature between the oblique and normally incident cases is due to differences in target hydrodynamics.
- In the normal iteration beam case the hydro evolves more slowly.
Significant SBS can be expected on NIF only if multibeam and/or seeding effects are important

- Simulations are underway with NIF profiles (LILAC).

- Expansion velocities are lower, and gradients are weaker.

- The gain in intensity $G < 17$ due to
  - High IAW damping in DT $\sim 0.3$
  - Lower laser intensities
  - Higher plasma temperature

- Crossing beam effects and seeding from critical surface could still give significant SBS.
  - Best investigated by simulation