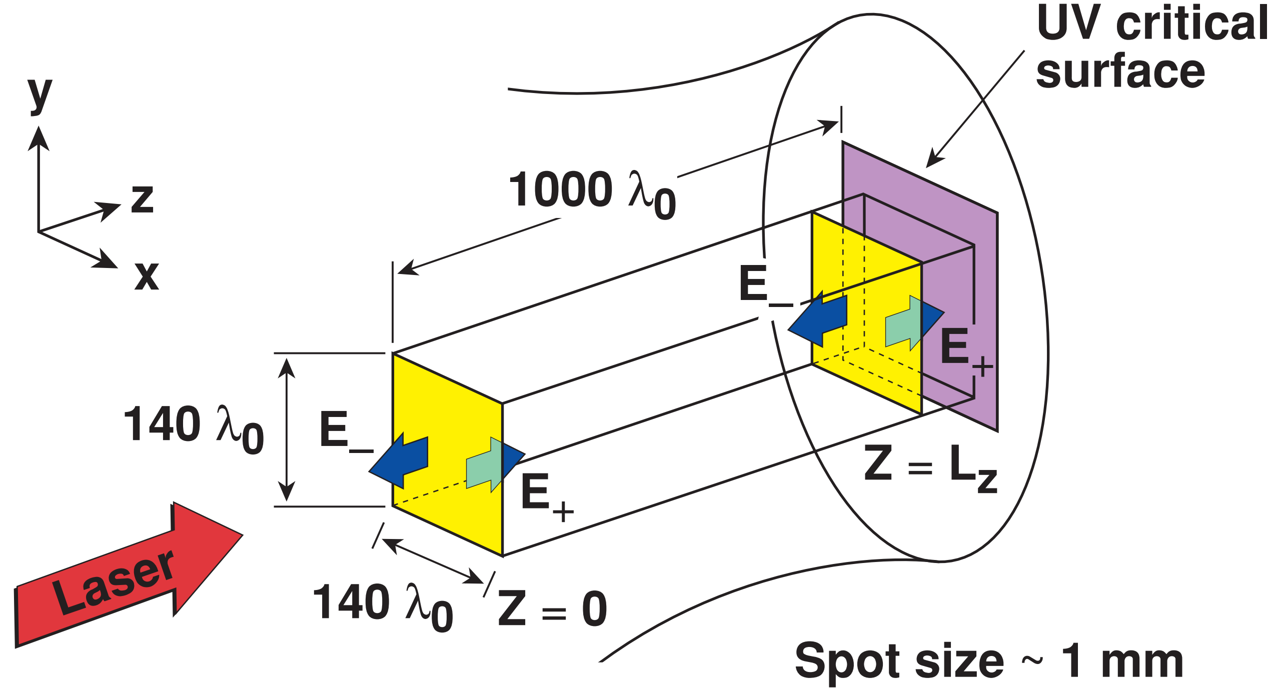
Modeling Laser–Plasma Interaction Physics Under Direct-Drive Inertial Confinement Fusion Conditions



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

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Conclusions

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

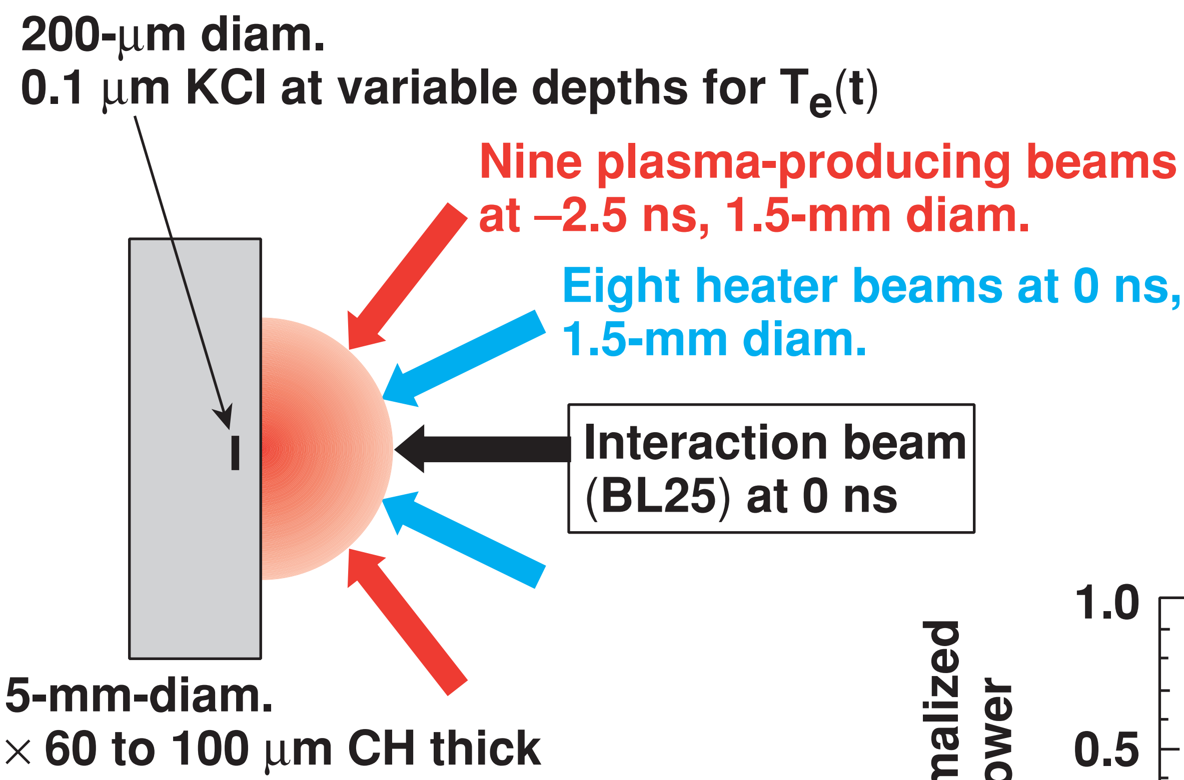
- First large-scale simulations relevant to direct-drive OMEGA LPI experiments
  - DPP beams with intensities in the range (4–16) 10^{14} W/cm^2
  - Favorable comparison of simulated backscatter with OMEGA experiments
  - SBS <1% in main part of pulse for intensities in the range (4–16) 10^{14} W/cm^2
  - Hydrodynamic evolution of "shelf" in plasma profile is critical.
  - Reflectivity is sensitive to details of the "shelf".

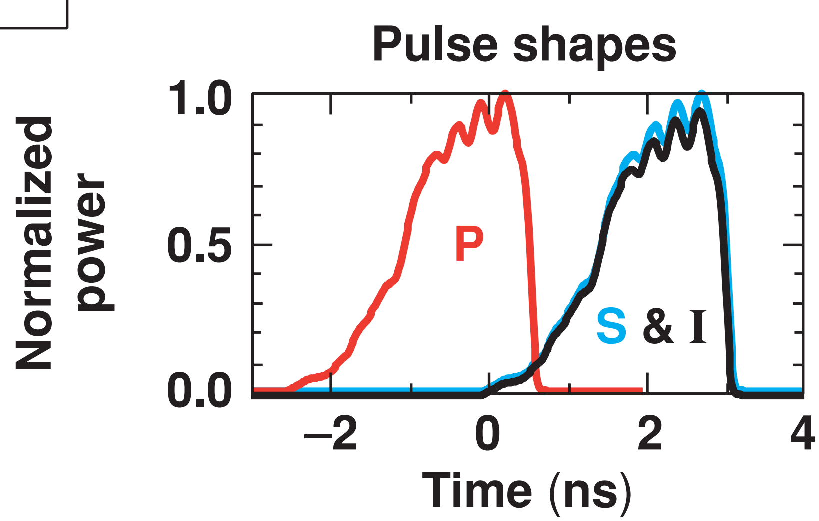
- Enhanced ion-wave fluctuations near quarter-critical surface are observed as a result of laser self-smoothing and low SBS reflectivities.
  - Plasma-induced smoothing threshold intensity near 10^{15} W/cm^2
  - Experimental evidence of TDP saturation near 10^{15} W/cm^2

Outline

- Collaboration with LLNL for pF3D
  - Direct-drive simulation geometry
  - Treatment of the critical surface
  - Plasma inhomogeneity modeled using *SAGE* data as an initial condition
- Simulations including backward SBS
  - Single DPP beam with averaged intensities in the range (4–16) 10^{14} W/cm^2
  - OMEGA experiments show two spectral features in backscatter, red and blue
  - Comparison of backscattered light with blue feature
  - Evidence for the importance of the "shelf" in expansion velocity
  - Extrapolation to NIF targets
- Enhanced ion-wave fluctuations near quarter-critical surface

NIF plasma conditions are produced on OMEGA with staggered multiple-beam irradiation of solid CH targets





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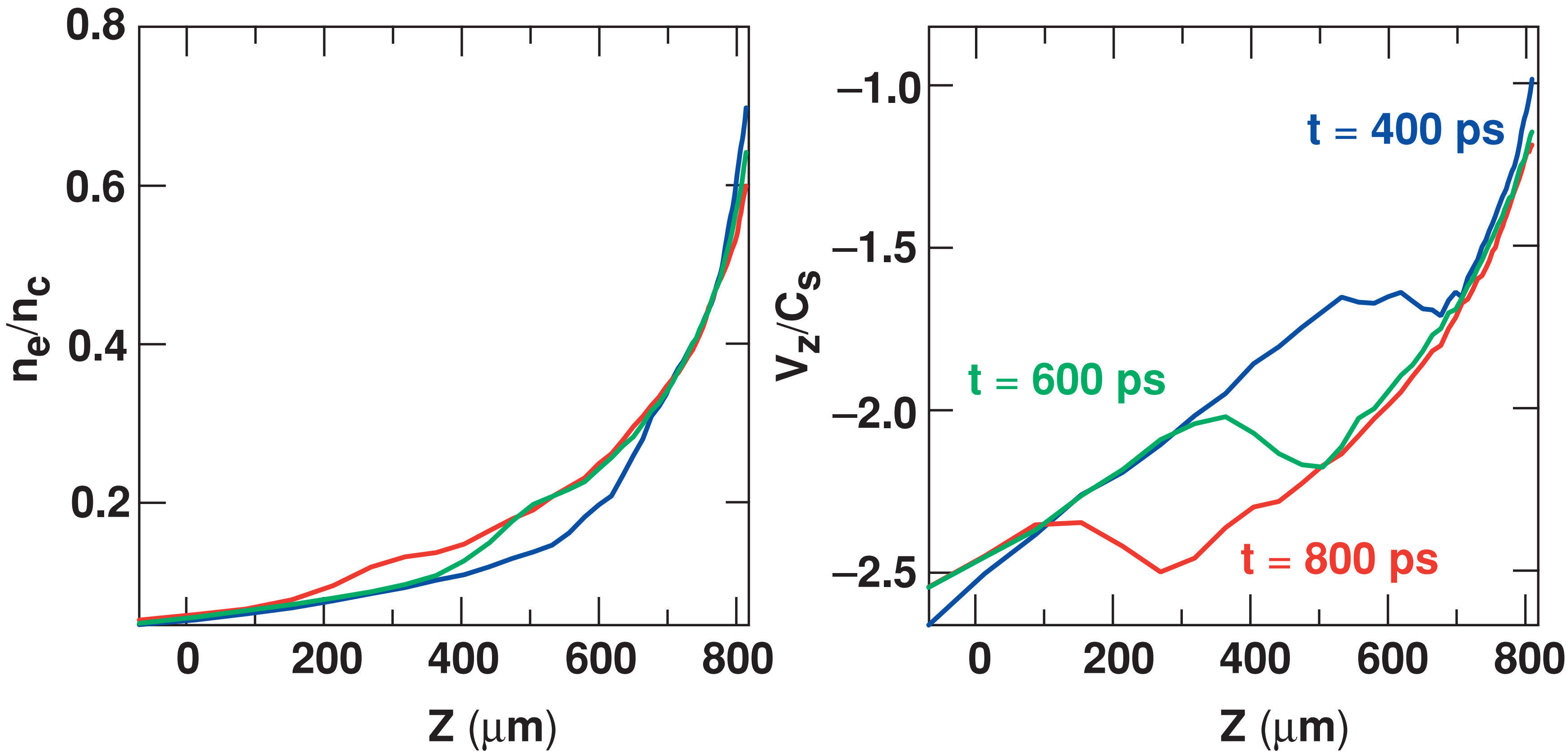
A "shelf" in the plasma expansion velocity is a common feature of all direct-drive experiments

UR LLE

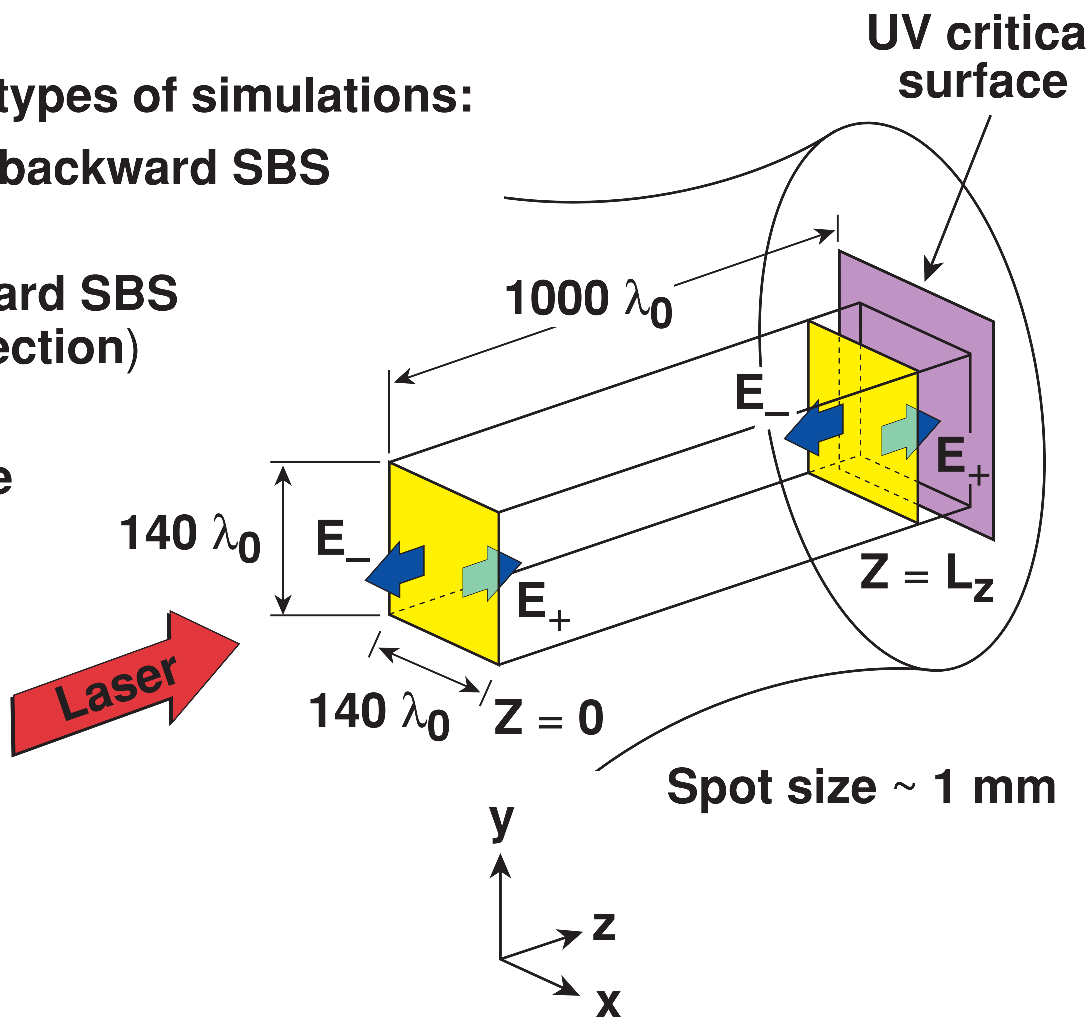
- Ablation due to the rising pulse of the interaction beam creates a shelf that propagates down the gradient with time.



TC5979

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)
- Currently the underdense and transcritical regions are treated separately.

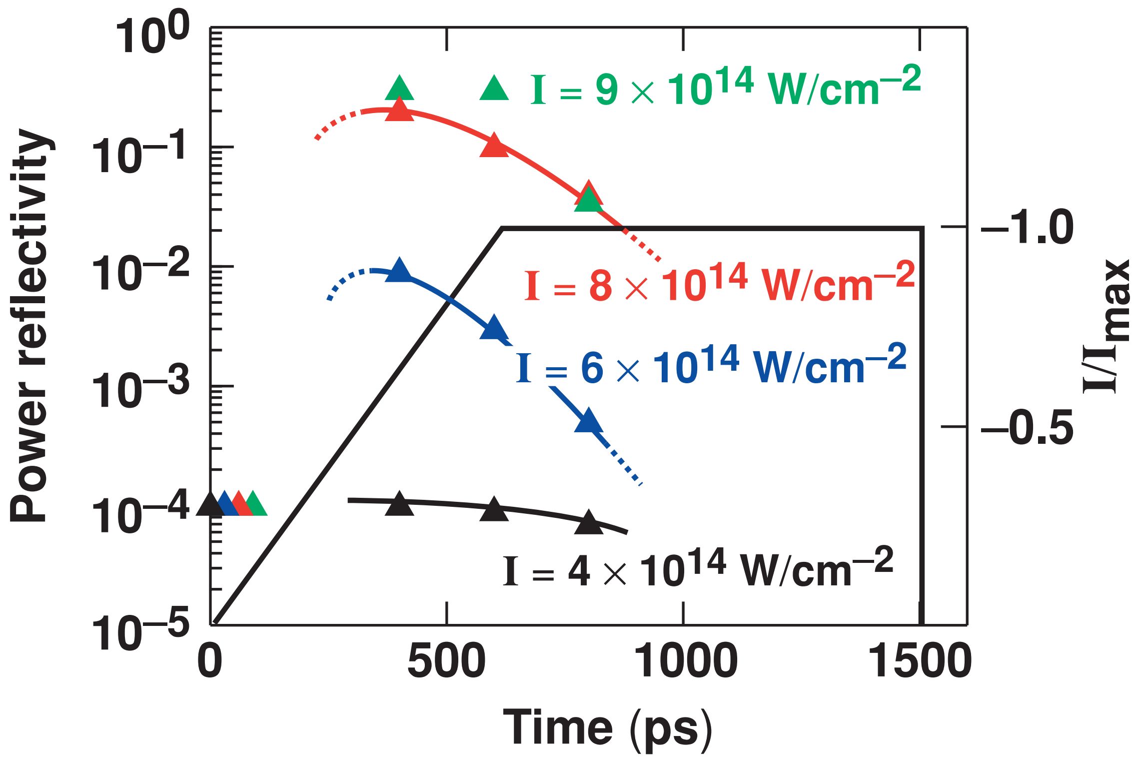


TC5980

The level and temporal dependence of the simulated SBS reflectivity are consistent with experiment

UR LLE

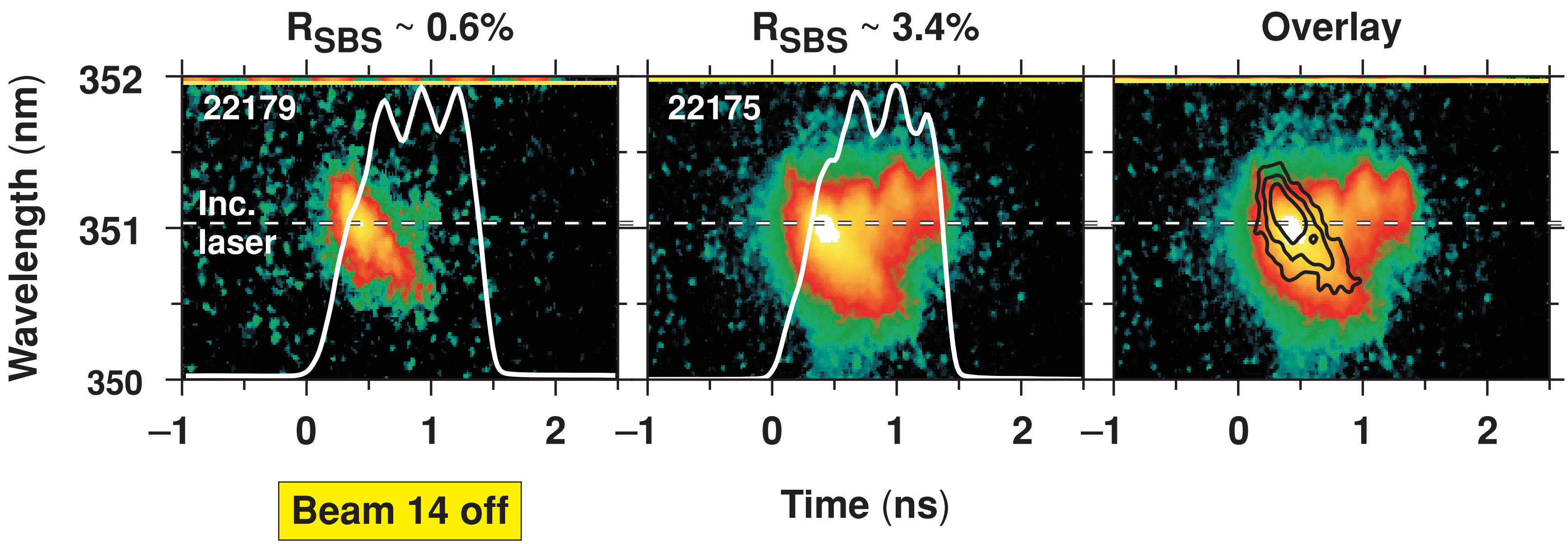
- The reflectivity has its maximum early in the laser pulse.
- During the later part of the pulse the reflectivity is less than a few percent for all simulated intensities.
- The reflectivity is not far from linear gain estimates.

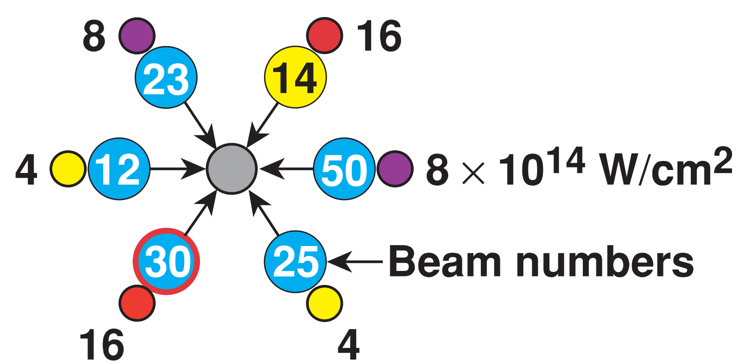


TC5981

Multiple-beam experiments are dominated by EM-seeded SBS backscattering

$I_{30} = 1.6 \times 10^{15}$ W/cm^2, SSD at 1-THz and PS





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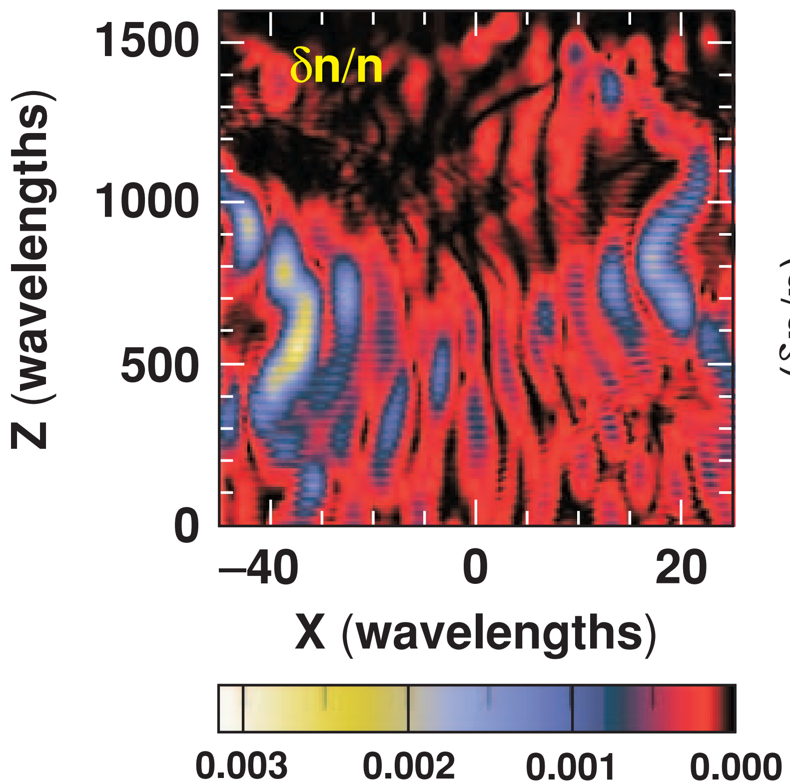
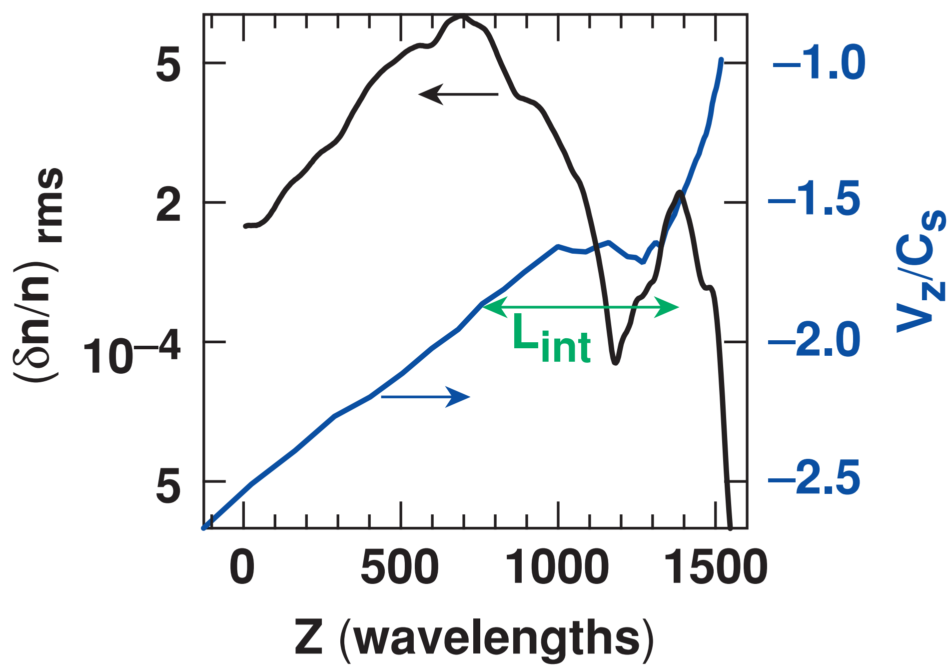
Backward SBS occurs primarily in the shelf of ablated material caused by the rising interaction beam

UR LLE

- 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.





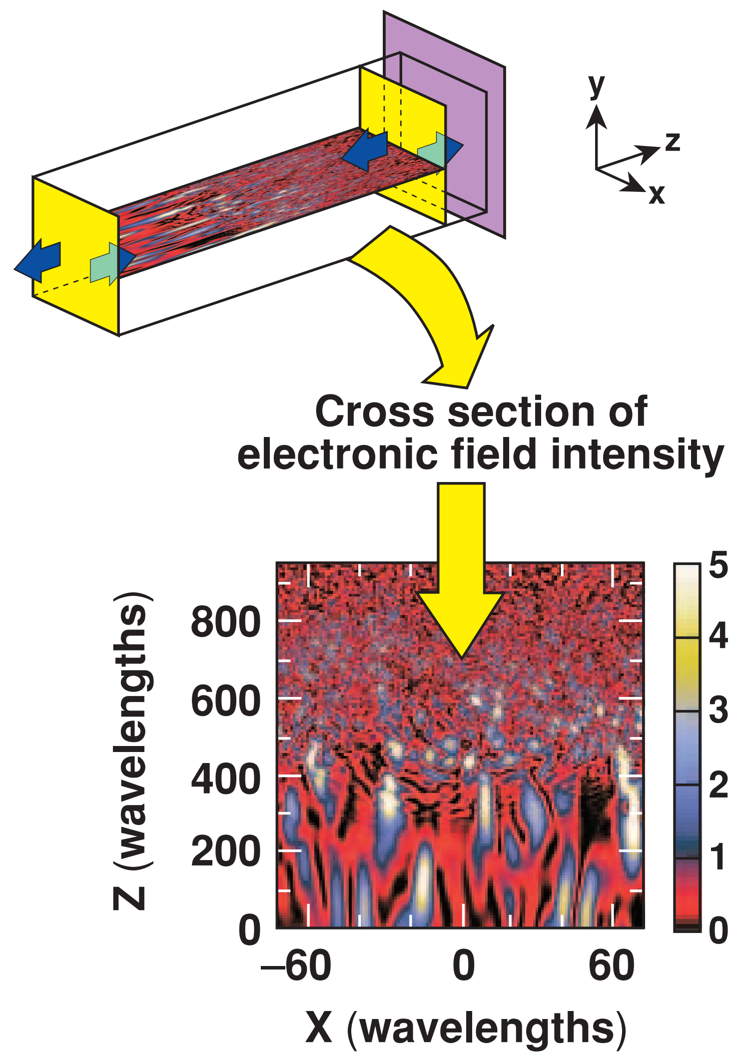
TC5982

For average laser intensities above 10^{15} W/cm^2, self-smoothing is active and wins the competition with SBS later in the pulse

- The condition for filament instability is achieved at quarter-critical for intensities above 10^{15} W/cm^2;

$$p = 0.39 \frac{I_{15}\,\lambda^2_{\mu m}}{T_{e,\,keV}} f^2 \frac{n_e}{n_c} \sim 0.2$$

- The SBS reflectivity is small later in the pulse due to steep gradients.
- At onset intensity the rms density fluctuations at the quarter-critical surface are a few percent.
- Connection with TPD saturation?



TC5983

Future direction

- Multiple crossing beams and EM seeding
- Quantify the effects of SSD and PS
- Better treatment of critical surface
  - Integration of full-wave solver