Theoretical Interpretation of SBS Observations in OMEGA Long-Scale-Length Plasma Experiments

R. W. Short, R. S. Craxton, W. Seka, and D. D. Meyerhofer
University of Rochester
Laboratory for Laser Energetics

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Summary

SBS arises primarily in “hot spots” and seems to be seeded by light reflected from critical

- Polarization smoothing (PS) reduces the level of SBS to that seen at half the incident intensity without PS, implying that SBS levels are determined by hot-spot intensities.

- Ion waves are strongly damped.

- The red-shifted portion of the spectrum appears to derive from light reflected from critical, but it is difficult to account for levels and shifts.
Outline

• Aspects of SBS spectra

• Ion-acoustic modes in multicomponent plasmas

• Strong-damping SBS model and calculation of growth factors in simulated profiles

• Summary and conclusions
SBS spectrum consists of distinct “red” and “blue” features

\[ I_{\text{peak}} = 7.4 \times 10^{14} \text{ W/cm}^2 \]
“Blue” feature depends exponentially on hot-spot intensity

![Graph showing intensity and reflectivity relationship for SBS blue (E). The graph includes data points for No PS, Rescaled PS, and PS conditions, with intensity plotted on the x-axis and reflectivity on the y-axis. The graph demonstrates an exponential increase in reflectivity with increasing intensity.]
“Red” feature depends linearly on hot-spot intensity

Reflectivity ($\times 10^{-3}$) vs. Intensity ($\times 10^{14}$)
All ion-acoustic modes are strongly damped
In strongly damped plasmas the SBS gain may be computed by integrating a local gain factor

- The equation for SBS intensity is\(^1\) \(\frac{\partial I_{\text{SBS}}}{\partial x} + \frac{I_{\text{SBS}}}{L_{\text{abs}}} = \frac{I_{\text{pump}} I_{\text{SBS}}}{L_{\text{gain}}}\).

Here, \(L_{\text{abs}}\) is the absorption length and \(L_{\text{gain}}\) is the local gain length:

\[
L_{\text{gain}}^{-1} = \frac{k_0}{4} \frac{n_e / n_c}{\sqrt{\cos^2 \theta - n_e / n_c}} \frac{m_e v_{\text{osc}}^2}{T_e} \left[ 1 + \frac{3T_i}{Z T_e} \right] \left( \frac{v_i}{\omega_s} \right) \left( \eta + \frac{v_i}{c_s} \right) \left( \eta^2 - 1 \right) \eta^2
\]

where \(p(\eta) = \frac{\left( \frac{v_i}{\omega_s} \right)^2 \eta}{\left( \eta^2 - 1 \right)^2 + \left( \frac{v_i}{\omega_s} \right)^2 \eta^2}\) and \(\eta = \frac{v_i}{c_s} \cos \theta + \frac{\omega_i}{\omega_s}\).

- The simulation code SAGE is used to provide the profiles of the plasma parameters over which the above equations are integrated.

The peak computed gain as a function of wavelength agrees well with “blue” feature.
At 5 ns, the velocity profile is flat around $n_c/10$
At oblique incidence, gains are somewhat larger and shifts smaller.

- Wavelength shift (nm)
  - Time = 5400 (ps)
  - Time = 4800 (ps)
  - Time = 4400 (ps)

Growth exponent vs. Wavelength shift (nm)
Even at lower intensities the time history of the red feature suggests SBS rather than simple reflection.

\[ I_{\text{peak}} = 1.7 \times 10^{14} \text{ W/cm}^2 \]
The present model does not account for some observed features of the SBS emission

- Levels of the “red” feature lie below those expected from simple inverse bremsstrahlung absorption.

- The increasing red shift at later times is not accounted for by the SBS gain factor or the bulk hydro motion.

- These phenomena may result from hot-spot behavior near critical, e.g., enhanced localized absorption and Doppler shift.
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