Numerical Simulations of the SSD-Smoothed Laser Beam Filamentation and FSBS in Plasma

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Introduction

- Analysis of the SBS dispersion equation suggests that near-forward SBS can be driven resonantly by the finite bandwidth of a SSD laser beam.[1]
- We have simulated the interaction of narrow-bandwidth (0.14-THz) and wide bandwidth (0.60-THz) light waves with ion-acoustic waves.
- In both cases near-forward SBS occurred, and the beam nonuniformity increased slightly.

[1] R. W. Short, 29th Annual Anomalous Absorption Conference, Monterey, CA, 14–18 June 1999.

A 2-D numerical model for SBS and filamentation was developed

- Our code solves the paraxial light-wave equation coupled with the ion-acoustic wave equation in t, z, and x.

- We used 1-D SSD boundary conditions for the laser beam

$$A(x,t) = A_0(x,t)e^{i\phi_{SSD}(x,t)}e^{i\phi_{DPP}(x)}$$

- $A_0(x,t)$: flat-top profile with a rise time of ~ 100 ps

- $\phi_{SSD}(x,t) = 3\delta_m \sin[2\pi\nu(t+\xi x)]$ with parameters relevant to OMEGA:

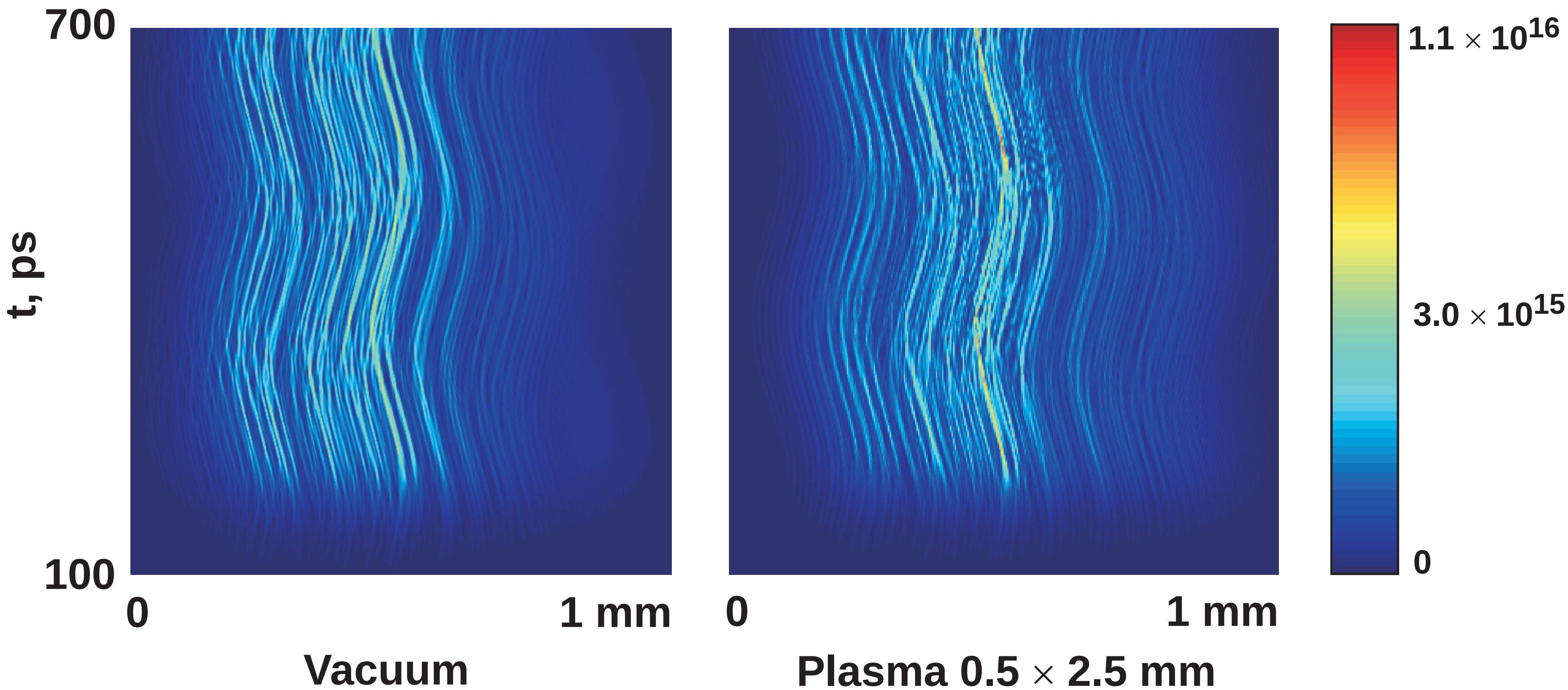
  modulation depth $\delta_m = 6.15, 7.89$
  modulation frequency $\nu_m = 3\,\mathrm{GHz}, 9\,\mathrm{GHz}$

  grating parameter $\xi = 1.11$ ns/m

  estimated bandwidth $\Delta\nu \simeq 2\nu_m\ (\delta_m + 2)$

Propagation through plasma changes the hot-spot intensity distribution

Intensity on the target plane during 700 ps



T = 2 keV n = 14% n_{cr} I_0 ~ 2.5 10^{14} W/cm^2

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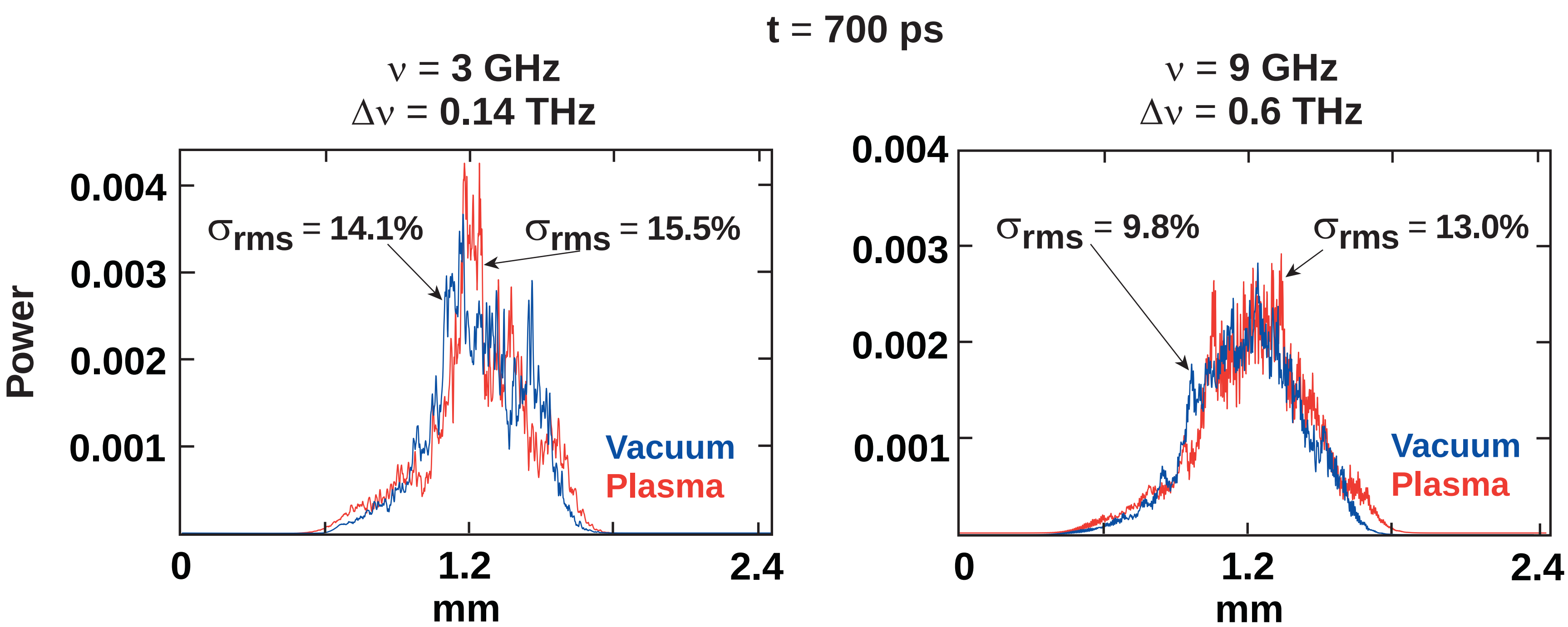
Propagation through plasma slightly increases the nonuniformity of a SSD-smoothed laser beam



$$\sigma_{rms}^2 = \frac{\int_{k \geq 0.04\,\mu m^{-1}}^{\infty} P_k^2 \, dk}{\int_{0}^{k < 0.04\,\mu m^{-1}} P_k^2 \, dk} \; ^*$$

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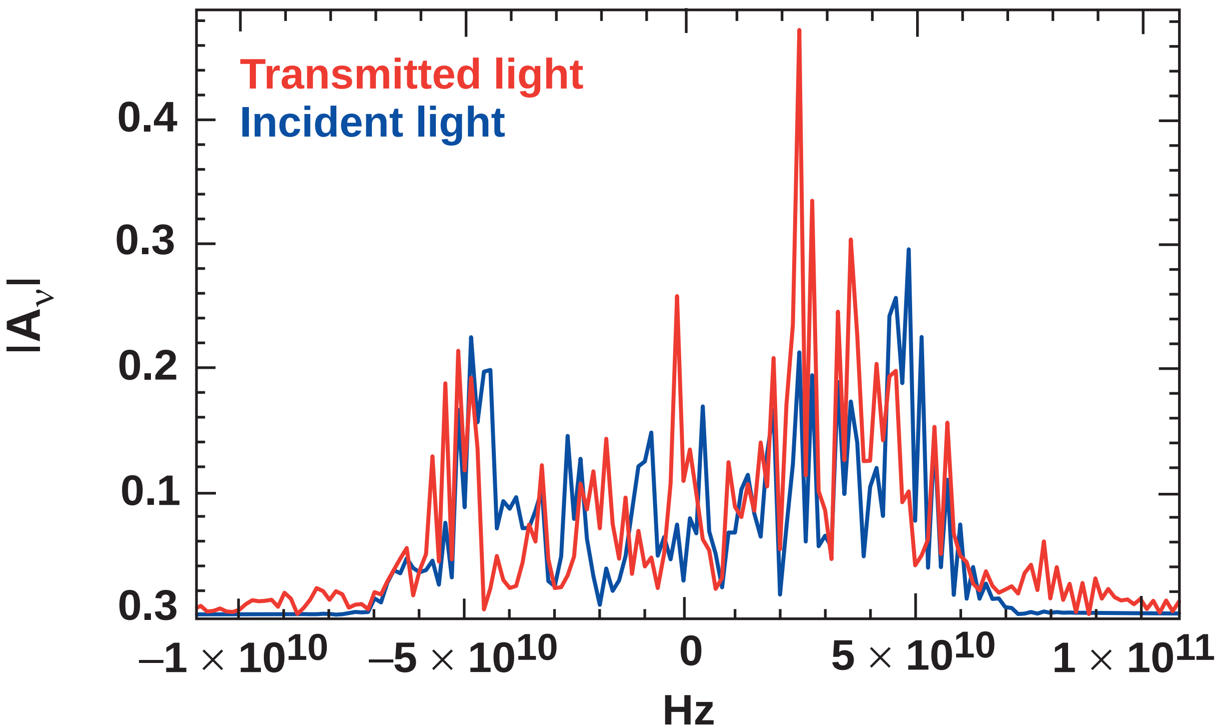
*LLE Review 79, 151, NTIS document DOE/SF/19960-317.

For low SSD modulation frequency the transmitted light spectrum is widened and reshifted



$I_0 \sim 2.5 \bullet 10^{14}$ W/cm^2; f# = 6.7; n = 14% n_{cr};

ν_m = 3 GHz; $\Delta\nu$ = 0.14 THz

- The blue shifted spectral components are characteristic of near-forward SBS*.

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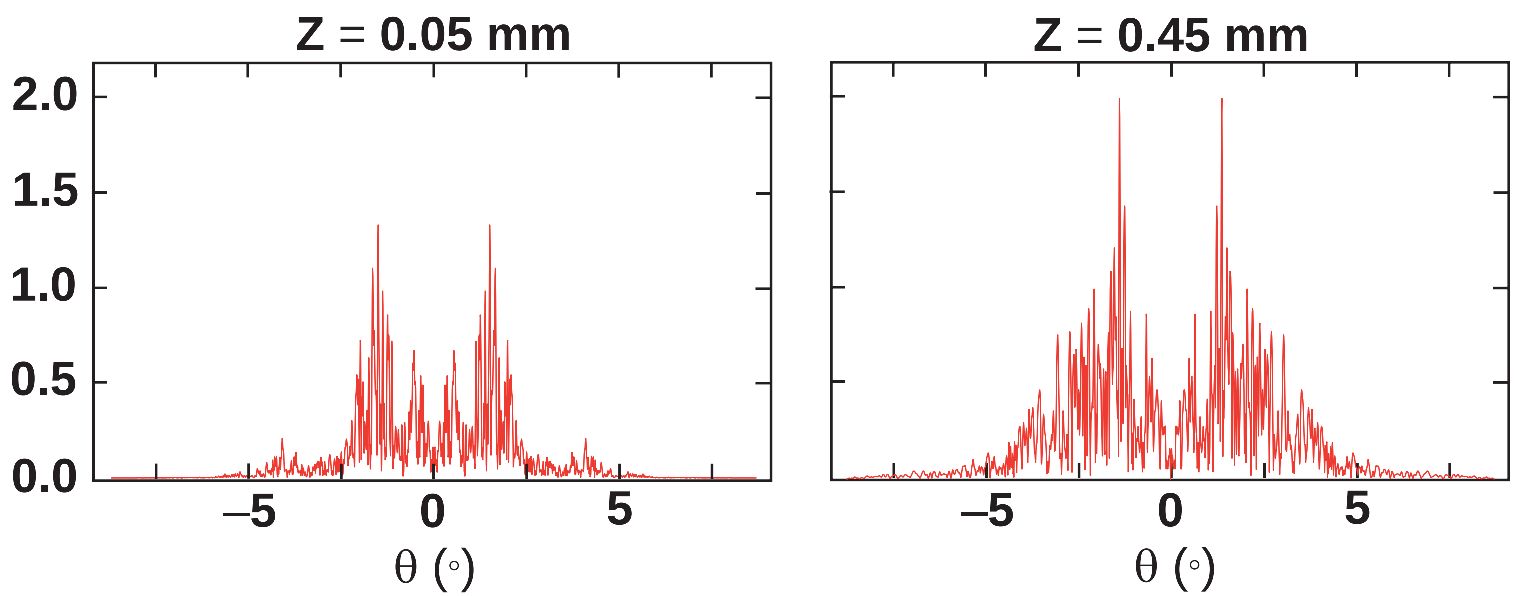
* McKinstrie, Li, and Kanaev, Phys. Plasma 4, 4227 (1997).

The ion-acoustic spectrum provides further evidence of near-forward SBS



$$\Delta\nu = \mathbf{0.14\ THz} \quad \left\langle \frac{\delta n}{n} \right\rangle \simeq 8\%$$

- Angles θ are related to wavenumbers k_{sx} by $k_{sx} = 2k_0 \sin(\theta/2)$.
- Energy is distributed uniformly across the spatial spectrum due to angular separation between neighboring lines $\Delta\theta$, determined from $k_{sx} = \frac{\omega_m}{c_s}$ is ~ 0.14°

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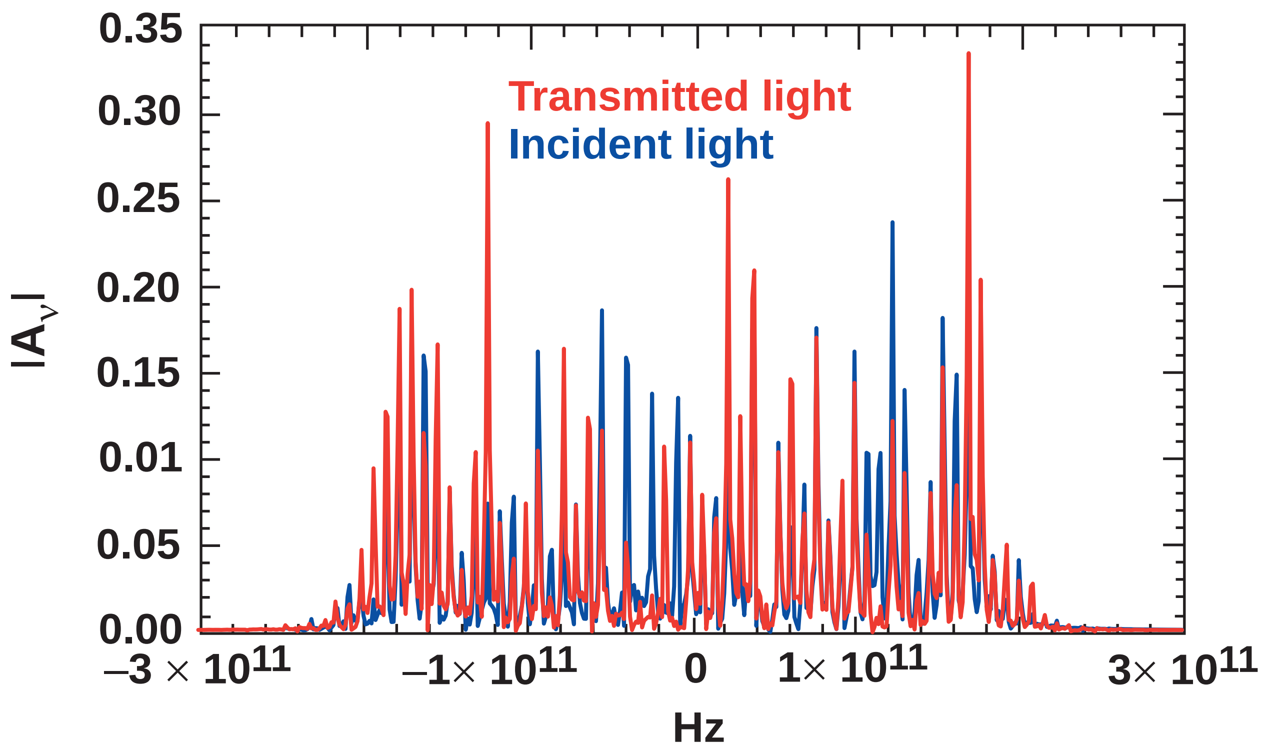
For high SSD modulation frequency the transmitted light spectrum exhibits power exchange between existing lines



$I_0 \sim 2.5 \bullet 10^{14}$ W/cm^2; f# = 6.7; n = 14% n_{cr};

ν_m = 9.0 GHz; $\Delta\nu$ = 0.60 THz

- We think that spectral broadening is limited by the aspect ratio of the speckles.

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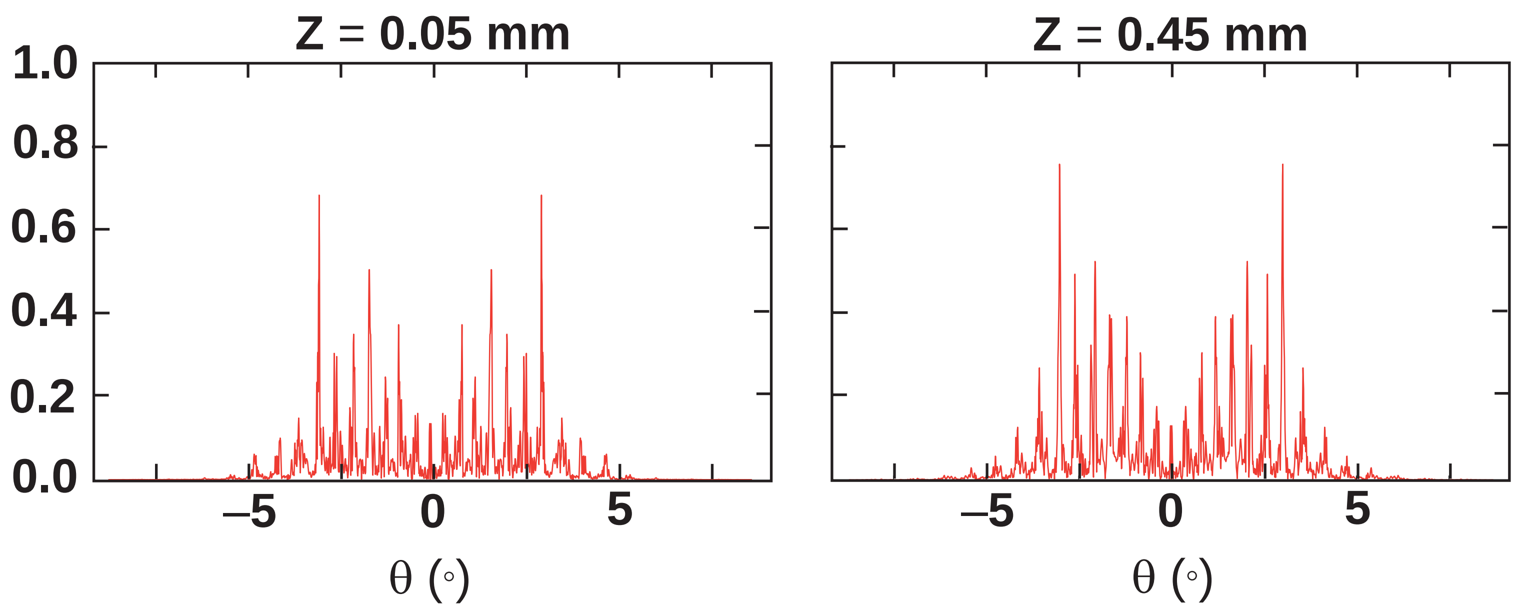
The ion-acoustic spectrum proves that power exchange is facilitated by near-forward SBS



$$\Delta\nu = \mathbf{0.6\ THz}\ \left\langle \frac{\delta n}{n} \right\rangle \simeq \mathbf{2\%}$$

- **Angular seperation between neighboring lines ($\Delta\theta \sim 0.41^\circ$) is consistent with $k_{sx} = \frac{\omega_m}{c_s}$**
- **Lines, multiple of $\Delta\theta$, indicate that every EM sideband interacts with every other EM sideband.**

Summary

Resonantly driven SBS was observed in simulation of SSD-smoothed beam propagation

- **For 3-GHz SSD modulation, transmitted light spectrum was widened and red shifted.**
- **For 9-GHz SSD modulation power was exchanged between the spectral components of the incident light wave.**
- **In both cases the beam nonuniformity increased slightly.**