Multibeam Laser–Plasma Interactions Lead to Localized Interaction Regions

Single-beam interactions

Multibeam interactions sharing a common daughter wave

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56th Annual Meeting of the American Physical Society
Division of Plasma Physics
New Orleans, LA
27–31 October 2014
Summary

There is ample experimental evidence for nonuniform energy deposition into various three-wave interaction processes

- Stimulated Brillouin scattering (SBS)
  - SBS backscatter is inherently nonuniform
  - Low-gain SBS sidescatter [cross-beam energy transfer (CBET)] significantly affects drive uniformity

- Stimulated Raman scattering (SRS) is filamentation-mediated in backscattering at high intensities

- Two-plasmon decay (TPD) is predominantly a multibeam process responding to overlapped intensity nonuniformities

All three-wave interaction processes have the potential to lead to drive nonuniformity over the surface of inertial confinement fusion (ICF) targets.
Collaborators


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The gain of three-wave interactions is intensity dependent, inherently causing nonuniform energy deposition.

- The effect is obvious for a backscattering instability (e.g., SBS)
- It applies to all laser–plasma instabilities (LPI’s), back- or sidescattering and multibeam instabilities (polarization!)
Low-gain SBS (CBET) leads to nonuniform laser drive for direct-drive ICF

- CBET was identified via scattered-light spectroscopy*
- CBET reduces absorption by ~10% to 20%
- Reduces hydrodynamic efficiency**
- Causes localized reduction in drive – low-order-mode perturbations
- Mitigation strategies are being investigated***

Intensity at $n_c/4$

- $I_{14}$
- $\sigma_{rms} \approx 6\%$
- Peak-to-valley: ~24%
- OMEGA cyro implosion

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**[I. V. Igumenshchev et al., Phys. Plasmas 17, 122708 (2010).*

***[D. H. Froula et al., NO4.00013, this conference.*
SBS is exacerbated by speckles and fast-rising laser pulses

- Fast-rising pulses
  - rapidly changing ablation rate
  - velocity plateau descends $\nabla n$

- $\sim 15\%$ instantaneous SBS backscatter ($\sim 6\%$ time integrated)
- $\sim 40\%$ locally because of intensity distribution
- SBS tends to be hot-spot driven
- SBS is sensitive to rapid changes in ablation rate

Single beam $I_{14} = 8$, no SSD*
Overlapped: $I_{14} = 45$
High-intensity spherical shock experiments are also prone to SRS backscattering

- SRS
  - very sensitive to SSD
  - filamentation mediated
  - $\leq 2\%$ backscattering without SSD

Single beam $I_{14} = 8$, no SSD
Overlapped: $I_{14} = 45$
Nonuniform energy deposition into TPD is visible in $\omega/2$ images of imploding targets.

Legend:
- $I_{14}$, linear
- Normalized overlapped intensity
- Landau cutoff (LC)
TPD in current National Ignition Facility (NIF) polar-drive (PD) implosions* occurs in clearly delimited regions of the target.

Potential TPD interaction not yet diagnosed on the NIF

* M. Hohenberger, CI1.00001, this conference.
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  - Low-gain SBS sidescatter [cross-beam energy transfer (CBET)] significantly affects drive uniformity

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