43rd Annual Anomalous

Absorption Conference

July 7-12, 2013 • Skamania Lodge • Stevenson, Washington

ANOMALOUS ABSORPTION CONFERENCE
JULY 7-12, 2013, SKAMANIA LODGE, STEVENSON, WA

Sunday, July 7, 2013 (Adams Room)

5:00 PM	Reception/Registration/Check-in (Red Bluff Mezzanine)
8:00 PM	Adjourn

Monday, July 8, 2013 (Stevenson Ballroom B)

9:00 AM	Hinkel, D. E.	**Welcome**	LLNL
Laser-Plasma Interactions		**Chair: E. A. Williams, LLNL**	
9:05 AM	Ren, C.	Laser-plasma interactions and hot electron generation in shock ignition	LLE
9:25 AM	Tsung, F. S.	Particle-in-Cell Simulations of Laser Plasma Interactions Relevant to Shock Ignition	UCLA
9:45 AM	Michel, P. A.	Time-resolved SBS measurements from 57 NIF beams over >200 shots using the laser drive diagnostics	LLNL
10:05 AM	Kruer, W. L.	Cooperative stimulated Brillouin scattering driven by overlapping, large spot laser beams	LLNL
10:25 AM	Chapman, T.	New insight into the parametric instability of ion acoustic waves	LLNL
10:45 AM	**BREAK**		
11:15 AM	Winjum, B. J.	PIC Simulations of Stimulated Raman Scattering Due to Interacting Laser Speckles	UCLA
11:35 AM	Rousseaux, C.	Experimental evidence of collective SRS driven in the picosecond, bispeckle laser-plasma interaction	CEA
11:55 AM	Williams, E. A.	Discussion	LLNL
12:30 PM	Adjourn		
7:30 PM	Hinkel, D.E.	National Ignition Facility: Recent Results (Stevenson Ballroom B)	LLNL
8:00 PM	**All**	**Poster Session (Hood Meeting Room)**	
P-1	Srinivasan, B.	The mitigating effect of magnetic fields and ion viscosity on Raylgieh-Taylor unstable ICF plasmas	LANL
P-2	Flippo, K.A.	Investigating Turbulent Mix in HEDLP Experiments	LANL
P-3	Krasheninnikova, N.	Symmetry Tuning with Cone Powers for Defect Induced Mix Experiment Implosions	LANL
P-4	Yi, S.A.	Beryllium Ignition Targets for Indirect Drive NIF Experiments	LANL
P-5	Michel, D. T.	Experimental Comparison of Hydrodynamic Efficiencies of Be, C, and CH Ablators in Spherical, Direct-Drive Implosions	LLE
P-6	Hu, S.X.	Understanding the Creation of NIF-Scale Plasmas on OMEGA EP for Laser-Plasma Instability Studies	LLE
P-7	Tableman, A.	Hybrid-PIC Simulations of Shock Formation in Laser-Irradiated Plasmas	UCLA
P-8	Tzoufras, M.	Self-guiding a laser pulse with a bulbous bow	UCLA
P-9	Winjum, B. J.	Kinetic simulations of the self-focusing and dissipation of finite-width electron plasma waves	UCLA
P-10	Tsung, F. S,	Particle-in-cell simulations of laser-plasma interactions near the quarter-critical surface	UCLA
P-11	Banks, J. W.	Steady electron plasma waves in 2D+2V	LLNL
P-12	Tzoufras, M.	Self-guiding a laser pulse with a bulbous bow	UCLA
P-13	Raynaud, M.	Improved Electron and Ion Acceleration via Relativistic Intense Laser Grating Target Interaction	CEA
P-14	DuBois, D.F.	Langmuir Caviation and Collapse in the Nonlinear Development of Two Plasmon Decay	Lodestar
P-15	Cheng, B./Kwan, T.	Scaling laws for NIF ignition	LANL
P-16	Vu, H.	Dependence of Hot Electron Generation on Ion Landau Damping in RPIC Simulations of the Two Plasmon Decay Instability	UCSD
P-17	Ho, D.		LLNL
P-18	Kyrala, G.		LANL

A break-out room has been reserved in the Jefferson meeting room located on the lower level

Tuesday, July 9, 2013 (Stevenson Ballroom B)

Cross-Beam Energy Transfer **Chair: J. L. Kline, LANL**

9:00 AM	Froula, D. H.	Implications of Two-State Focal Zooming on OMEGA to Mitigate Cross-Beam Energy Transfer	LLE
9:20 AM	Marozas, J. A.	Comparison of 2-D DRACO Cross-Beam Energy Transfer Simulations with OMEGA and NIF Experiments	LLE
9:40 AM	Maximov, A. V.	Nonlinear Interaction Between Multiple Incoherent Laser Beams in the Plasmas of Direct-Drive ICF	LLE
10:00 AM	Edgell, D. H.	Cross-Beam Energy Transfer in Polar-Drive Implosions on OMEGA and the NIF	LLE
10:20 AM	**BREAK**		
10:50 AM	Williams, E. A.	Four-Wave Mixing at the National Ignition Facility	LLNL
11:10 AM	Hinkel, D. E.	The Quartraum: a platform for investigating cross-beam energy transfer	LLNL
11:30 AM	Casanova, M.	Laser-plasma interaction and beam crossing effects	CEA
11:50 AM	Li, C. K.	Current Filaments, Plasma Flow and their Spontaneous Fields in Laser-Hohlraum Interactions	MIT
12:10 PM	Adjourn		
7:30 PM	Michel, P. A.	A review of cross-beam energy transfer	LLNL
8:00 PM	Kline, J. L.	Discussion Section: Cross-Beam Energy Transfer	LANL
10:00 PM	Adjourn		

Wednesday, July 10, 2013 (Stevenson Ballroom B)

Two-Plasmon Decay **Chair: C. Ren, LLE**

9:00 AM	Solodov, A. A.	Measurements of the Divergence of Fast Electrons in Laser-Irradiated Spherical Targets	LLE
9:20 AM	Follett, R. K.	Ultraviolet Thomson Scattering from Two-Plasmon Decay Driven Electron Plasma Waves at Quarter-Critical Densities	LLE
9:40 AM	Moody, J. D.	Stimulated Raman and Brillouin backscatter as a remote laser power sensor in high-energy-density plasmas	LLNL
10:00 AM	Zhang, J.	Absolute Threshold of Two-Plasmon Decay Driven by Multiple Laser Beams	LLE
10:20 AM	**BREAK**		
10:50 AM	Short, R. W.	The Effects of Beam Geometry and Polarization on Two-Plasmon Decay Driven by Multiple Laser Beams	LLE
11:10 AM	Haberberger, D.	Measurements of Long-Scale-Length Plasma Density Profiles Using Refractometry	LLE
11:30 AM	All	Business Meeting	
12:30 PM	Adjourn		
7:30 PM	Seka, W.	A review of the Two-Plasmon Decay	LLE
8:00 PM	Kruer, W. L.	Discussion Section: 2ωp	UCD
10:00 PM	Adjourn		

Thursday, July 11, 2013 (Stevenson Ballroom B)

Rad-Hydro and LPI **Chair: M. J. Schmitt, LANL**

9:00 AM	Masson-Laborde, P-E.	Hydrodynamic modeling of gold bubble expansion and laser-plasma interaction in mm-long gas-filled hohlraum experiments on the LIL facility	CEA
9:20 AM	Divol, L.	Indirect-drive exploding pusher on the NIF: an (almost) one-shock-system for ICF physics studies	LLNL
9:40 AM	Rosen, M.D.	Low-Density, Gas-Filled Hohlraum: A platform to study hohlraum physics that is intermediate between Au Spheres and Ignition Hohlraums	LLNL
10:00 AM	John Mortraus ~~Salmonson, J. D.~~	~~A 2D Hot Spot Mix Model for Diagnosing Performance of NIF Ignition Experiments~~	LLE ~~LLNL~~
10:20 AM	**BREAK**		
10:50 AM	Strozzi, D. J.	NIF Hohlraum Experiments at Room Temperature	LLNL
11:10 AM	Kline, J. L.	Optimizing Hohlraum Performance via Case-to-Capsule Ratio for ICF	LANL
11:30 AM	Schmitt, M. J.	Simulations of direct drive targets on Omega and NIF	LANL
11:50 AM	Krashenninikova	Symmetry Tuning with Cone Powers for Defect Induced Mix Experiment Implosions	LANL
12:10 PM	Schmitt, M. J.	Discussion Section: Rad-Hydro and LPI	LANL
1:00 PM	Adjourn		
7:00 PM	Working Business Dinner	Skamania Lodge Garden Patio	

Friday, July 12, 2013 (Stevenson Ballroom B)

Kinetic Effects		Chair: Frank Tsung, UCLA	
9:00 AM	Amendt, P. A.	Shock-driven resistive heating in mixed species thermonuclear fuels	LLNL
9:20 AM	Wilks, S. C.	Validation of LSP Hybrid Fluid and Kinetic Plasma Shock Simulations	LLNL
9:40 AM	Bellei, C.	Ion reflection at shock fronts: implications for mix	LLNL
10:00 AM	Kagan, G.	Multi-species effects in inertially confined plasmas	LANL
10:20 AM	**BREAK**		
10:50 AM	Ellis, I.N.	A Comparison of Stopping Power Theories with Results from Particle-in-Cell and Molecular Dynamics Codes	UCLA
11:10 AM	Tableman, A.	Vlasov-Fokker-Planck modeling of High-Energy-Density Plasmas	UCLA
11:30 AM	Tsung, F.	Discussion Section: Kinetic Effects	UCLA
12:25 PM	Hinkel, D. E.	Closing Comments	
12:30 PM	Conference Ends		

NU MIX
MF uniform MIX Experiment

A break-out room has been reserved in the Jefferson meeting room located on the lower level

❖ Morning Session ❖
Stevenson Ballroom B

9:00 AM	Laser-Plasma Interactions
11:55 AM	Discussion Section: LPI
	E.A. Williams, LLNL

❖ Evening Session ❖
Stevenson Ballroom B

7:30 PM	Recent NIF Results
	D.E. Hinkel, LLNL

❖ Poster Session ❖
Hood Meeting Room

8:00 PM	Poster Session
10:00 PM	Adjourn

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Laser-plasma interactions and hot electron generation in shock ignition*

C. Ren, R. Yan, and J. Li
Laboratory for Laser Energetics and University of Rochester
W. B. Mori
University of California, Los Angeles

We present recent particle-in-cell (PIC) simulations for laser-plasma interactions in the recent 40+20-beam spherical shock ignition experiments on the Omega laser facility[1]. Two-dimensional PIC simulations including electron-ion collisions and lasting more than 10 ps show a bursting pattern in both plasma waves and hot electron fluxes, which are attributed to the interplay between stimulated Raman scattering (SRS) and two-plasmon decay (TPD) instabilities. The observed hot electron temperatures compare favorably to those measured in the experiments. These results can help us understand better laser-plasma interactions in the ignition phase of the shock ignition scheme.

1. W. Theobald, R. Nora, M. Lafon, *et al.*, Phys. Plasmas **19,** 102706 (2012)

* This work was supported by the U.S. Department of Energy under under Grant No. DE-FC02-04ER54789 and Cooperate Agreement No. DE-FC52- 08NA28302, by NSF under Grant No. PHY-0903797, and by NSFC under Grant No. 11129503. The research used resources of NERSC.

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Particle-in-Cell Simulations of Laser Plasma Interactions Relevant to Shock Ignition*

F. S. Tsung, M. Tzoufras, W. B. Mori
University of California, Los Angeles

We present simulation results on the laser-plasma interaction for density and intensity ranges relevant to shock ignition. These simulations show the importance of instabilities near the quarter critical surface and the importance of higher dimensional simulations. The saturation mechanism and the recurrence rate of the instability will also be presented.

*This work is supported by DOE DE-FG52-09NA29552 and through a University of Rochester subcontract No. 415025-G.

Prefer Oral Presentation

HFHI Modes dominate at low $k_\perp$

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Time-resolved SBS measurements from 57 NIF beams over >200 shots using the laser drive diagnostics*

P. Michel, B. J. MacGowan, B. Raymond, K. La Fortune, M. Spaeth, K. Manes, J-M Di Nicola, L. Divol, J.D. Moody, L. Peterson and D. A. Callahan
Lawrence Livermore National Laboratory

Only three quadruplets of NIF beams are equipped with full backscatter diagnostics (the Full Aperture Backscatter System (FABS) and Near Backscatter imager (NBI)). However, Stimulated Brillouin Scattering (SBS) reflections off the final optics assembly on NIF beams can be sent back into the laser Drive Diagnostics (DrD), installed on at least one beam on every NIF quad. As a result, time-resolved SBS measurements from the 57 NIF beams equipped with DrD have been collected for all NIF shots since 2009. In this presentation, we will summarize some of the main findings from these measurements, such as:

- the study of the random beam-to-beam azimuthal variations of SBS within a same laser cone;
- the systematic azimuthal variations in SBS due to the presence of various diagnostic elements in NIF targets (diagnostic windows, VISAR cone etc.) generating higher SBS on a few selected beams;
- the systematic variations in SBS between beams of a same quadruplet due to cross-beam energy transfer (CBET) induced by flows inside the targets;
- the systematic variations in SBS due to changes in CBET when beams are being dropped or used as backlighters.

The consequences from such variations on drive symmetry for various types of targets will be discussed.
re-absorption of the backscattered light on laser energy deposition.

Great paper on SBS —> W. Seka PRL 89 175002 (2002) —>

* This work was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344.

* Should request this information from DIME shots
– Might be able to assess CBET between beam cones

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Cooperative stimulated Brillouin scattering driven by overlapping, large spot laser beams*

William L. Kruer*, Robert K. Kirkwood, Pierre Michel, and David P. Turnbull
Lawrence Livermore National Laboratory

In NIF hohlraums, large regions of plasma are irradiated with intense overlapping and large spot laser beams. In this regime, cooperative excitation of stimulated scattering can become a significant effect. Indeed, the potential importance of cooperative scattering has already been illustrated in calculations[1] of cross beam energy transfer, where many crossing laser beams enhance the energy of another beam- a form of (generally nonresonant) cooperative SBS in the forward direction. Similarly, cooperative interactions are thought to play some role in scattering in the backward direction[2]. Here we consider an interesting special case in which all the beams in a cone resonantly drive an ion sound wave along the hohlraum axis. This results in laser light being scattered backward along the cone. The frequency of this scattered light differs from that of the light directly backscattered by each beam, although there may be cross talk if the frequency of the backscattered light is sufficiently broad. A simple theory is presented, and some experiments to isolate and characterize cooperative scattering are discussed.

* LLNL Consultant
1.Pierre Michel *et. al. Phys.* Plasmas **17**, 056305 (2010).
2. R. Kirkwood *et. al.* Phys. Plasmas, **18**, 056311 (2011).
3. W. Seka *et. al.*, Phys. Rev. Lett. **89**, 175002 (2002).

* This work was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344.

— Ask Wolfe is early spike is blowby
— Bill has paper from Summer School - that is electronic
could request a copy

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New insight into the parametric instability of ion acoustic waves†

T. Chapman[1,*], R. L. Berger[1], B. I. Cohen[1], E. A. Williams[1], and S. Brunner[2]
[1]*Lawrence Livermore National Laboratory, P.O. Box 808, Livermore, CA 94551, USA*
[2]*Centre de Recherches en Physique des Plasmas, Association EURATOM-Confédération Suisse, Ecole Polytechnique Fédéral de Lausanne, CH-1015 Lausanne, Switzerland*
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The Ion Acoustic Wave (IAW) decay instability has been shown in theoretical studies to be an important saturation mechanism for Stimulated Brillouin Scatter [1, 2], possibly relevant to Inertial Confinement Fusion experiments [3]. Previous detailed studies [1, 2, 4] have used Particle-In-Cell (PIC) simulations to explore the decay process. These studies were limited by low resolution in k-space (8 simulated fundamental wavelengths) and the inherently high noise of PIC methods, which may seed instabilities at a level such that the nature of the instability is obscured.

We present results of a study of the parametric instability of IAWs using the 1D1V Vlasov code SAPRISTI. Utilizing extremely low noise (numerical double precision) and high resolution in k–space (64 simulated fundamental wavelengths), we show for the first time the fine structure of the growth of IAWs below the fundamental wave and indeed between each of its harmonics up to the 64th harmonic. Theoretical work [5] has previously suggested that the nature of the instability should be sensitive to the sign of the mismatch in frequency between the pump IAW and its decay waves arising due to the nonlinear dispersion of IAWs and nonlinear frequency shifts (both fluid and kinetic). This sensitivity is investigated by means of varying ZT_e/T_i over a broad range of values.

[1] B. I. Cohen *et al.*, Phys. Plasmas **4**, 956 (1997).
[2] C. Riconda *et al.*, Phys. Rev. Lett. **94**, 055003 (2005).
[3] N. B. Meezan *et al.*, Phys. Plasmas **17**, 056304 (2010).
[4] B. I. Cohen *et al.*, Phys. Plasmas **16**, 032701 (2009).
[5] D. Pesme, C. Riconda, and V. T. Tikhonchuk, Phys. Plasmas **12**, 092101 (2005).

† *This work was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344 and funded by the Laboratory Research and Development Program at LLNL under project tracking code 12-ERD-061.*

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PIC Simulations of Stimulated Raman Scattering Due to Interacting Laser Speckles*

B. J. Winjum, F. S. Tsung, and W. B. Mori
University of California Los Angeles

The laser beams in inertial confinement fusion experiments consist of a distribution of high-intensity speckles, a percentage of which are above-threshold for stimulated Raman scattering (SRS). SRS can also be driven in below-threshold speckles due to inter-speckle interactions via waves and particles. We present 2D PIC simulations with the code OSIRIS for both homogenous and inhomogenous plasmas, showing conditions for which (1) scattered light waves, (2) plasma waves, and (3) hot electrons generated by SRS in above-threshold speckles can also trigger SRS in neighboring, below-threshold speckles. The three intermediary elements are systematically studied through tailored two-speckle simulations in which we control the relative placement and polarizations of the speckles. All three intermediaries can stimulate SRS in below-threshold speckles, though scattered light is the most efficient mechanism for inter-speckle SRS. Simulations of multi-speckle ensembles show that SRS triggered by scattered light can lead to pump depletion dominating the recurrence of SRS.

* This work was supported by the DOE under Grants No. DE-FG52-09NA29552 and No. DE-NA0001833 and by the NSF under Grant No. NSF-Phy-0904039; simulations were performed on the UCLA Hoffman2 Cluster, NERSC's Hopper, and NCSA's Blue Waters.

- Nice moves of e^- moving down density gradient
- One speckle exciting a low intensity speckle - like Yin

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Experimental evidence of collective SRS driven in the picosecond, bispeckle laser-plasma interaction

C. Rousseaux[1], S.D. Baton[2], D. Bénisti[1], K. Glize[1], L. Gremillet[1], L. Lancia[3]

[1]CEA, DAM, DIF, 91297 Arpajon, France
[2]LULI, Ecole Polytechnique, 91128 Palaiseau Cedex
[3]Università di Roma "La Sapienza", Via Scarpa 14-16, 00161 Roma, Italy

By means of two-independently compressed, short laser pulses, stimulated Raman backscattering (B-SRS) has been excited by two speckles in the side-by-side configuration. The goal of this first experiment was to investigate how a weak intensity hot spot laser could turn out to be unstable with respect to B-SRS due to the presence of a higher intensity hot spot undergoing SRS and located tens microns away from the first one.

The experiment has been performed in LULI laboratory at the ELFIE facility (formally the newly upgraded 100-TW laser facility). The two 1ω, jitter-free, 1.5ps FWHM laser pulses were focused in a preformed, He gas jet plasma, at electron density and temperature of respectively $0.06n_c$ and 0.3keV. The beams were focused by the same f/12 off-axis parabola into 13μm FWHM focal spots. For this experiment, we chose (i) to cross the polarizations of the two beams, (ii) to set the lateral distance between two hot spots to 80μm, and (iii) to vary the time-delay between them. B-SRS was characterized by means of 0.3ps time- and space resolved Thomson diagnostics, jointly with f/5 backscattered energy diagnostic to get SRS reflectivities.

Despite the relatively large distance between the two laser speckles, the experiment unambiguously shows B-SRS of the weak speckle (intensity $I_{weak} \approx 10^{15}$W/cm^2) in the presence of the strong one ($I_{strong} \approx 10^{16}$W/cm^2): SRS abruptly increases from near threshold to an estimated 5% to 10% reflectivity. Surprisingly, the effect on the weak speckle is evidenced to keep going on a long time, up to 20ps after the strong pulse in our experimental conditions. As electromagnetic seeding from the strong speckle is precluded here, the role of the SRS-generated hot electron population seems to be essential in the triggering of B-SRS in the weak speckle.

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National Ignition Facility: Recent Results*

D. E. Hinkel
Lawrence Livermore National Laboratory

The National Ignition Facility (NIF) has been conducting experiments using the indirect drive approach, with the goal of achieving thermonuclear burn in the laboratory. In these experiments, up to 1.8 MJ of ultraviolet light (0.35 micron) is injected into 1 cm scale cylindrical gold or gold-coated uranium, gas-filled hohlraums, to implode 1mm radius plastic capsules containing solid DT fuel layers. Experiments have demonstrated the ability to achieve densities of 600-800 gm/cc, along with neutron yields within a factor of five necessary to enter the regime of alpha particle heating. To achieve these results, experimental platforms were developed to carefully control key attributes of the implosion. This talk will review the progress toward ignition.

* This work was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344.

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The mitigating effect of magnetic fields and ion viscosity on Rayleigh-Taylor unstable ICF plasmas

B. Srinivasan and X.-Z. Tang
Los Alamos National Laboratory

Rayleigh-Taylor instability (RTI), an interchange instability commonly observed in inertial confinement fusion (ICF) capsules, can generate magnetic fields at the gas-ice interface and at the ice-ablator interface during target implosion. The focus here is on the gas-ice interface where the temperature gradient is the largest. Nonlinear evolution of RTI leads to undesirable mixing of hot and cold plasmas and enhances hot spot energy loss. A plasma model that includes both ion and electron physics, Hall-magnetohydrodynamics (Hall-MHD), is used to self-consistently study the generation and growth of magnetic fields in RTI.

The Biermann battery effect, i.e. the noncolinearity in the electron density and temperature gradients, is responsible for magnetic field generation which is related to ion fluid vorticity generation by RTI. In the presence of an externally applied magnetic field, the MHD dynamo further amplifies the magnetic field and aligns it with the cold/hot interface. The self-generated out-of-plane magnetic fields grow to magnitudes of 10^2-10^3 T for ICF relevant parameter regimes. While this is dynamically insignificant due to the plasma pressure far exceeding the magnetic pressure, it can significantly reduce perpendicular electron thermal conductivity by a factor of 2-10. Externally applied magnetic fields can further reduce electron thermal conductivity while large external fields can also mitigate RT mix. Such a reduction in thermal conductivity perpendicular to the magnetic field contributes to lowering of radial energy transport in the implosion target [1-3]. At high temperatures (keV range), the hot-spot ion viscosity also plays a significant role in mitigating energy loss by damping short-wavelength RTI. Mechanisms to achieve energy loss mitigation and RT mix mitigation will be presented for ICF-relevant parameter regimes. Nonlinear saturation of the peak vorticity and the peak magnetic field will be described using a visco-resistive Hall-MHD model.

[1] B. Srinivasan, G. Dimonte and X.-Z. Tang, Phys. Rev. Lett. **108**, 165002 (2012)
[2] B. Srinivasan and X.-Z. Tang, Phys. Plasmas, **19**, 082703 (2012)
[3] B. Srinivasan and X.-Z. Tang, Phys. Plasmas, **20**, 056307 (2013)

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Investigating Turbulent Mix in HEDLP Experiments*

Kirk A. Flippo[1], Forrest Doss[1], Eric Loomis[1], Leslie Welser-Sherrill[1], John L. Kline[1], Barbara Devolder[1], Jim Fincke[1]
Los Alamos National Laboratory

1) Los Alamos National Laboratory, Los Alamos, NM USA
kflippo@lanl.gov

We report on initial experiments planned for and performed at the NIF and Omega to investigate turbulent mix on a platform initially developed for the Omega laser facility and scaled up for NIF. We are investigating turbulence-driven mix from two colliding shocks and sheared layers resulting from Richtmeyer-Meshkov and Kelvin-Helmholtz instabilities, such as those expected in ICF ignition capsule. Two shocks were generated at either end of cylindrical, CH foams, and the evolution of a Ti or Al tracer layer in the center plane or at one end of the foam was measured using point-projection radiography as it is either shocked twice or sheared. Comparison of this data with simulations using the Besnard-Harlow-Rauenzahn (BHR) model is used. BHR is intended for turbulent transport in fluids with large density variations and has the ability to improve our predictive capability for ICF experiments.

*Los Alamos National Laboratory, an affirmative action/equal opportunity employer, is operated by the Los Alamos National Security, LLC for the National Nuclear Security Administration of the U.S. Department of Energy under contract DE-AC52-06NA25396.

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Symmetry Tuning with Cone Powers for Defect Induced Mix Experiment Implosions* LA-UR-12-23046

Natalia S. Krasheninnikova
M. Schmitt, T. Murphy, J. Cobble, I. Tregillis, G. Kyrala, P. Bradley, P. Hakel, S. Hsu, R. Kanzleiter, K. Obrey, R. Shah, J. Baumgaertel, S. Batha
Los Alamos National Laboratory

Recent Defect Induced Mix Experiment (DIME) campaigns on the National Ignition Facility (NIF) and Laboratory for Laser Energetics' Omega laser have demonstrated the effectiveness of cone power tuning to control the implosion symmetry in the Polar Direct Drive[1] (PDD) configuration. DIME aims to assess the effects of mix on the thermonuclear burn during a thin-shell capsule implosion. Plastic shell capsules doped with mid-Z material (such as Ti or Ge) and filled with 5 atm of deuterium, are ablatively driven in a PDD laser configuration to a convergence ratio of ~7. Time-gated, spectrally and spatially resolved, dopant emission images characterize the mix and temperature morphology during the implosion, while the neutron diagnostics concurrently give the information about the burn. Symmetry should be maintained throughout the implosions to achieve high neutron yield and optimum spectroscopic signal. Two and 3-D computer simulations using the 3-D radiation-hydrodynamics code HYDRA[2] were performed to validate and optimize implosion symmetry using cone power tuning. In particular, January 2013 PDD Omega campaign confirmed P_2 tunability with cone powers producing prolate, circular, and oblate capsule implosions that were in agreement with code predictions. Furthermore, experiments on NIF demonstrated that by reducing the energy in polar cones (23.5^o and 30^o) by 25%, the P_2 Legendre mode was reduced to <1% around bang time from previous experimental values[3] of -15%. However, during FY12-13 NIF DIME campaigns, polar and equatorial high resolution self-emission images revealed a complex internal structure around the equator, which was not seen in HYDRA simulations and could be attributed to LPI effects. Subsequent DIME campaigns on NIF were able to eliminate this equatorial feature by reducing the laser drive from $2 \cdot 10^{15}$ W/cm^2 to 1, substantiating the LPI hypothesis.

[1] A. M. Cok, et. al, Phys. Plasmas 15, 082705 (2008)
[2] M. M. Marinak, et. al, Phys. Plasmas 3, 2070 (1996)
[3] M. J. Schmitt, et. al, Phys. Plasmas 20, 056310 (2013)

*Work performed by Los Alamos National Laboratory under contract DE-AC52-06NA25396 for the National Nuclear Security Administration of the U.S. Department of Energy.

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Beryllium Ignition Targets for Indirect Drive NIF Experiments*

S. A. Yi, A. N. Simakov, D. C. Wilson, and J. L. Kline
Los Alamos National Laboratory
J. D. Salmonson, D. S. Clark, J. L. Milovich, and M. M. Marinak
Lawrence Livermore National Laboratory

Beryllium ablators have the advantage of lower opacity and therefore higher ablation rate, pressure, and velocity [1,2] than plastic ablators. Previous NIF beryllium target designs were developed using more optimistic hohlraum drives than NIF experiments indicate, as well as less accurate atomic configuration models; thus, an updated design is necessary. Here, we present our recent work on such a design. We consider a 1.8 MJ, 500 TW NIF laser pulse, and assume the standard 5.75 mm hohlraum. We employ the LLNL radiation-hydrodynamics code HYDRA and use 2D integrated simulations to optimize the main implosion characteristics with respect to the hohlraum fill gas density, laser beam pointing, and cross-beam energy transfer. Taking into account recent NIF experimental results that suggest the hohlraum radiation delivers a spectrally harder and less powerful drive than previously thought, we assume a 12-15% backscatter loss and an arbitrary 15% power loss in the fourth pulse. With this degraded drive and employing the new DCA detailed atomic configuration model, we scan the (ablator thickness/DT ice thickness/Cu-dopant level) parameter space to produce target capsule candidates having the standard NIF dopant-layer pyramid and generating fusion yields of up to ~28 MJ. We then study the hydrodynamic stability of the candidates by performing 2D capsule-only simulations driven by a radiation diffusion frequency dependent source (FDS) extracted from the integrated simulations. We show that our capsule design tolerates 1.5 times the specified surface roughness of the LLNL Rev. 3 beryllium capsule design with almost no reduction in yield. In addition, we calculate the relative contribution of each surface or material interface within the capsule to the instability growth and show that the inner fuel layer surface roughness is the dominant source of the hotspot distortion. We also show that increased instability growth due to larger M-band fraction in the radiation drive can be mitigated through the use of either higher-doped or thicker dopant layers.

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* This work was supported by the U.S. Department of Energy NNSA Inertial Confinement Fusion Program.

43rd Annual Anomalous
Absorption Conference
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Experimental Comparison of Hydrodynamic Efficiencies of Be, C, and CH Ablators in Spherical Direct-Drive Implosions

D. T. Michel, V. N. Goncharov, I. V. Igumenshchev, P. B. Radha,
S. X. Hu, W. Seka, and D. H. Froula
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A 20% increase in the implosion velocity is observed when using a Be ablator compared to a C or CH ablator in OMEGA experiments. Spherical implosions of 860-μm-diam targets were used. The shell thickness was varied for the different materials to maintain a constant ablator mass. The results are consistent for experiments conducted at both low (5×10^{14} W/cm^2) and high (8×10^{14} W/cm^2) overlapped intensities. Implosion velocities were measured with 5% accuracy by imaging the soft x-ray radiation emitted by the imploding target.[1] The unabsorbed laser power was measured with a series diagnostics around the target chamber. A comparable amount of unabsorbed power was measured for the three materials for a given intensity, consistent with *LILAC* simulations that include cross-beam energy transfer. At high intensity, *LILAC* simulations accurately reproduce the measured shell trajectories and show that the hydrodynamic efficiency is increased by 20% for the Be ablators and 7% for the C ablators compared to CH. Calculations indicate that this is primarily a result of the increase in the mass ablation rate, which scales with the mass density at the critical surface $\varrho_c = (Am_p/Z)n_c$, where A and Z are the average atomic mass and atomic number of the ions, respectively, m_p is the proton mass, and n_c is the critical electron density for 351 nm light.[2] For Be, $A/Z = 2.25$, which is 20% higher than for CH.

This material is based upon work supported by the Department of Energy National Nuclear Security Administration under Award Number DE-NA0001944, the University of Rochester, and the New York State Energy Research and Development Authority. The support of DOE does not constitute an endorsement by DOE of the views expressed in this article.

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Understanding the Creation of NIF-Scale Plasmas on OMEGA EP for Laser–Plasma Instability Studies*

S. X. Hu, D. H. Edgell, D. H. Froula, V. N. Goncharov, D. T. Michel, J. F. Myatt, S. Skupsky, and B. Yaakobi
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This work reports on analyses of laser-intensity and phase-plate-size scalings for producing NIF-scale plasmas on the OMEGA EP Laser System. It is essential to understand laser–plasma instabilities (LPI) in long-scale-length plasmas ($L_n \sim 500\ \mu$m) for direct-drive ignition on the National Ignition Facility (NIF) since the two-plasmon–decay (TPD) instability may grow above its threshold. To understand and develop mitigation strategies for the TPD instability in NIF-scale plasmas, a series of long-scale-length plasma experiments has been performed at the Omega Laser Facility. Two-dimensional *DRACO* simulations for these experiments indicated that (1) ignition-relevant long-scale-length plasmas of L_n approaching ~400 μm have been created for planar targets; (2) the density scale length at n_{qc} scales as $L_n(\mu\text{m}) \simeq \left(R_{DPP}/I^{1/4}\right)$; and (3) the coronal electron temperature T_e at n_{qc} scales as $T_e(\text{keV}) \simeq 0.95 \times \sqrt{I}$, with the incident intensity (I) measured in 10^{14} W/cm^2 for plasmas created on both OMEGA and OMEGA EP configurations with different-sized (R_{DPP}) distributed phase plates (DPP's). These intensity scalings[1] are found to be in good agreement with the self-similar model predictions. *DRACO* simulations show that NIF-scale ignition plasmas of $L_n \simeq 500\ \mu$m can be created on OMEGA EP with concave spherical half-shells illuminated from inside. Direct measurements of plasma density scale length in the quarter-critical regime are underway for such TPD experiments. These experiments and analyses on the plasma characterization will help better understand the TPD instability and its mitigation strategies.

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* This material is based upon work supported by the Department of Energy National Nuclear Security Administration under Award Number DE-NA0001944, the University of Rochester, and the New York State Energy Research and Development Authority. The support of DOE does not constitute an endorsement by DOE of the views expressed in this article.

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Hybrid-PIC Simulations of Shock Formation in Laser-Irradiated Plasmas *

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University of California Los Angeles

F. Fiuza
Lawrence Livermore National Laboratory

Shock generation by hot electron beams (with intensities ranging from 10^{14} W/cm^2 to 10^{16} W/cm^2) impinging on high density targets (~10^{24} /cm^3) is investigated using a 1D hybrid-PIC version of OSIRIS. The hybrid-PIC code uses a fluid model to follow electron transport at high densities. In these simulations an electron cathode is used as a proxy for hot electrons generated in under-dense regions by laser-plasma interactions. This approach enables control over the composition and energy distribution of the hot electrons entering the high density region, which, in turn, allows the direct study of hot electron energy deposition and the corresponding shock structure. Understanding how to harness the hot electrons to enhance shock formation will aid in designing Shock Ignition ICF targets with improved yield.

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Self-guiding a laser pulse with a bulbous bow*

M. Tzoufras, F. S. Tsung, W. B. Mori, A. Sahai
University of California, Los Angeles

Self-guiding of an ultra-intense laser pulse requires a suitable modification of the refractive index to build up rapidly, before the main body of the pulse passes by. For ultra-short single-frequency pulses this occurs within a plasma wavelength and a large portion of the leading edge is subject to diffraction. Nevertheless, if the body of the pulse survives for a sufficiently long distance, the concomitant changes in its spectral content result in highly localized absorption, such that the energy of the leading edge of the pulse is absorbed before it can diffract. To illustrate these mechanisms and optimize laser wakefield accelerators we propose a pulse profile with a "bulbous bow", that is an ultra-short ultra-intense pulse with a longer lower-intensity precursor that produces the necessary modification to the index of refraction. The wake-field behind such a pulse is more stable, contains more energy, is sustained longer, and the corresponding de-phasing length is extended.

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Prefer Poster

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Kinetic simulations of the self-focusing and dissipation of finite-width electron plasma waves*

B. J. Winjum[1], R. L. Berger[2], T. Chapman[2], J. W. Banks[2], S. Brunner[3], V. K. Decyk[1], and W. B. Mori[1]
[1]*University of California Los Angeles*
[2]*Lawrence Livermore National Laboratory*
[3]*Ecole Polytechnique Fédéral de Lausanne*

Two-dimensional kinetic simulations, both Vlasov and particle-in-cell, are presented that show the evolution of the field and electron distribution of finite-width, nonlinear electron plasma waves (EPW) for a range of $k\lambda_D$ centered about 1/3, where k is the EPW wavenumber and λ_D is the electron Debye length. The intrinsically intertwined effects of self-focusing and dissipation of field energy caused by electron trapping are studied. The simulated systems are hundreds of wavelengths long in the transverse direction but one wavelength long and periodic in the propagation direction to exclude the complicating effects of longitudinal modulational or decay instabilities. The ratio of the growth rate of transverse modulational instability to the field energy dissipation rate sets a threshold for the EPW to exhibit self-focusing effects similar to a purely self-focusing wave. These effects include the increase of EPW amplitude on axis as the EPW narrows, the time to peak amplitude, and the narrow EPW width at peak amplitude. The analysis for varying $k\lambda_D$ will also show that the ratio of the transverse localization rate to the nonlinear frequency shift is approximately constant for different $k\lambda_D$.

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Particle-in-cell Simulations of laser plasma interactions near the quarter critical surface*

F. S. Tsung(1), B. B. Afeyan(2), W. B. Mori(1)

We present simulation results on the laser-plasma interaction near the quarter critical surface under conditions relevant to inertial fusion. Under these conditions, the high frequency hybrid instability (HFHI) where the backward going daughter wave have mixed polarizations, is likely to be dominant. In high temperature plasmas where HFHI modes is dominant the absorption level can be high (up to 40%) for systems which are below the two plasmon threshold. This result implies, for laser pulses with a long (compared to the instability growth time, in the order of 1ps) rise time, the mixed polarization modes with small perpendicular wavenumber will play a even more dominant role. The effects of finite spot-size due to laser speckles, and the interaction of overlapping speckles will also be investigated..

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2 Polymath Research Inc., Pleasanton, CA.

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Prefer Poster Session

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Steady electron plasma waves in 2D+2V

J. W. Banks,_ R. L. Berger, and T. Chapman
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(Dated: May 9, 2013)

In this poster we present results from an investigation concerning the existence of steady traveling electron-plasma waves in 2 dimensions. We present simulation results from the 2D+2V Vlasov code LOKI, and give a strong indication of a 2D counterpart to the well-known Bernstein-Green-Kruskal (BGK) mode. Waves are driven in a quiescent plasma using an externally imposed electric field and then allowed to freely propagate. After the driver is turned o_, the nature of the solution is investigated. We give evidence that steady traveling waves do exist for periodic domains whose size transverse to the propagation direction is small enough when compared with 2_=(k_De). For larger transverse domains, the solution is found to evolve toward a structure more characteristic of smaller domains. The minimum size for decay into shorter wavelength modes is also discussed.

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Improved Electron and Ion Acceleration via Relativistic Intense Laser Grating Target Interaction

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A two-dimensional PIC numerical study of the enhanced electron and proton acceleration using thin solid structured targets ($\leq 10\ \lambda_0$) in the interaction of a high intensity (10^{19}-10^{20} W/cm^2) ultra-short ($\leq$ 100 fs) laser pulse is presented here. An overdense plasma with an electron density $n_e=100n_c$ is considered and the grating parameters are chosen so that the resonant excitation of a surface plasma wave is achieved at an oblique laser incidence of 30° [1]. In the case where the surface wave is excited we find an enhancement of the maximum ion energy of a factor ~ 2 compared to the cases where the target surface is flat [2]. This increase is correlated to the efficient electron heating when the surface wave is excited.

The simulation are in good agreement with a recent experimental investigation in which the use of ultrahigh laser contrast ($\sim 10^{12}$) allowed to demonstrate for the first time an enhanced laser-target coupling via surface plasma wave excitation in the relativistic regime of ultra-high intensity [3].

This work was performed using HPC resources from the GENCI-CCRT project t2012056851.

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Langmuir Cavitation and Collapse in the Nonlinear Development of Two Plasmon Decay *

D.F.DuBois** and **D.A. Russell**, *Lodestar Research Corp*. Boulder, CO,
H.X. Vu, *U. of California, San Diego*, and **J.F. Myatt**, *Laboratory for Laser Energetics, U. of Rochester*, NY

Several parametric instabilities: the so called parametric decay instability (PDI), at critical density, stimulated Raman scattering (SRS), in low Landau damping regimes, and two plasmon decay (TPD), are predicted to develop into a nonlinear state of "strong Langmuir turbulence" (SLT). This state is characterized by many localized Langmuir excitations-"cavitons"- which collapse to dimensions of a few electron Debye lengths, driven by the ponderomotive pressure of the localized electric fields, giving up their energy to accelerated electrons. A common signature of these phenomena is a spectrum of Langmuir oscillations lying below the linear Bohm-Gross dispersion. The nonlinear stage of TPD, the decay of the laser into two Langmuir waves (LWs), is predicted[1] to saturate in SLT. Explicit local space-time movies showing individual collapse events in TPD simulations will be shown as well as global frequency spectra displaying Langmuir excitations off the linear LW dispersion curves. The models used are the extended Zakharov (ZAK) models, the fully kinetic reduced particle-in-cell (RPIC) model, and the hybrid quasilinear Zakharov (QZAK) model. ZAK predictions have been verified[2] in detail in Thomson scattering observations of SLT excited by the PDI in the ionosphere: the decay of a strong radio wave into a LW and an ion acoustic wave. We will discuss SLT signatures for laser-plasma experiments. For both forward and backward SRS, a state of SLT is excited in regimes of low Landau damping of the LWs where kinetic inflation[3] due to electron trapping is not significant. In the TPD simulations[1] a large number of cavitons constitute a Gaussian random processes where a caviton temperature can be defined which is found to be linearly proportional to the computed hot electron temperature. From a theorem due to Alder, the auto correlation function of the LW electric field envelope is proportional to the shape of the peak caviton fields, yielding structures of the expected shape and size.

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** retired Fellow, LANL.

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Dependence of Hot Electron Generation on Ion Landau Damping in RPIC Simulations of the Two Plasmon Decay Instability*

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[4] *Laboratory for Laser Energetics, University of Rochester, Rochester, NY 14623*

The kinetic reduced-description particle-in-cell (RPIC) simulation technique has been applied to study the nonlinear stage of the two-plasmon decay (TPD) instability in an inhomogeneous plasma driven by crossed laser beams and the dependence of the hot electron flux on the ion Landau damping. The ion Landau damping is varied by changing the ion temperature. Otherwise identical RPIC simulations are performed, and the results indicate an observable dependence of the hot electron flux with respect to ion Landau damping. It is observed that decreasing the ion Landau damping leads to a significant decrease in the hot electron flux level, consistent with quasilinear Zakharov simulations and experimental trends. Spectral diagnostics (ion acoustic and Langmuir waves), hot electron diagnostics, and caviton correlator will be shown to examine the underlying physics.

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Scaling laws for NIF ignition*

Baolian Cheng, Thomas J. T. Kwan, Yi-Ming Wang, and Steven H. Batha
Los Alamos National Laboratory

We have developed an analytical physics model from fundamental physics principles and used the reduced 1-D model to derive a thermonuclear ignition criterion and implosion energy scaling laws applicable to ICF capsules. The scaling laws relate the fuel pressure and the minimum implosion energy required for ignition to the peak implosion velocity and the equation of state (EOS) of the pusher and the hot fuel. When a specific low entropy adiabat path is used for the cold fuel, the new scaling laws recover the ignition threshold factor (ITF) dependence on the implosion velocity, but when a high entropy adiabat path is chosen, the model agrees with recent measurements.

* This work was performed under the auspices of the U.S. Department of Energy by Los Alamos National Laboratory under contract DE-AC52-06NA25396 and by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344.

❖ Morning Session ❖
Stevenson Ballroom B

9:00 AM	Cross-Beam Energy Transfer
12:20 PM	Adjourn

❖ Evening Session ❖
Stevenson Ballroom B

7:30 PM	A review of cross-beam energy transfer P.A. Michel, LLNL
8:00 PM	Discussion Section: Cross-Beam Energy Transfer J.L. Kline, LANL

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Zoomed phase plate

Implications of Two-State Focal Zooming on OMEGA to Mitigate Cross-Beam Energy Transfer

ZPP's

D. H. Froula, T. J. Kessler, I. V. Igumenshchev, S. X. Hu, R. Betti,* V. N. Goncharov, H. Huang, E. Hill, J. H. Kelly, D. D. Meyerhofer,* A. Shvydky, and J. D. Zuegel
Laboratory for Laser Energetics, University of Rochester,
**also at Departments of Mechanical Engineering and Physics*

Cross-beam energy transfer (CBET) during OMEGA low-adiabat cryogenic experiments reduces the hydrodynamic efficiency by 35%, which lowers the calculated one-dimensional (1-D) yield by nearly an order of magnitude. CBET can be mitigated by reducing the diameter of the laser beams relative to the target diameter. Reducing the diameter of the laser beams after a sufficient conduction zone has been generated (two-state zooming) is predicted to maintain low-mode uniformity while mitigating CBET. A radially varying phase plate is proposed to implement two-state zooming on OMEGA. A beam propagating through the central half-diameter of the phase plate will produce a large spot, while a beam propagating through the outer annular region of the phase plate will produce a narrower spot. To produce the required two-state near-field laser beam profile, a picket driver with smoothing by spectral dispersion (SSD) would pass through an apodizer, forming a beam of half the standard diameter. A second main-pulse driver would co-propagate without SSD through its own apodizer, forming a full-diameter annular beam. Because of the limited energy capacity of OMEGA, this will limit the total energy on target to ~75% of the maximum currently available. One-dimensional hydrodynamic simulations, using the calculated laser spots produced by the proposed zooming scheme on OMEGA, show that implementing zooming on OMEGA will increase the implosion velocity by 15%, resulting in a factor of ~3 increase in the neutron yield, even when accounting for the 6 kJ of lost on-target energy. The resulting increase in the hydrodynamic efficiency (1.7×) is a consequence of the mitigation of CBET and the more normally-incident laser rays. Two-dimensional hydrodynamic simulations that neglect imprint show that the conduction zone produced during the pickets is sufficient to smooth the overlapped nonuniformities imposed by the smaller-diameter beams during the main drive. When including the increased imprint level that results from the smaller-diameter laser beams during the pickets, the neutron yield is reduced by a factor of 3. Alternate schemes for zooming will be discussed that improve the imprint power spectrum by judicious selection of the spatial shape of the laser beam during the pickets. Demonstrating zooming on OMEGA would validate a viable direct-drive CBET mitigation scheme and establish a hydrodynamically equivalent implosion pathway to direct-drive ignition.

This material is based upon work supported by the Department of Energy National Nuclear Security Administration under Award Number DE-NA0001944, the University of Rochester, and the New York State Energy Research and Development Authority. The support of DOE does not constitute an endorsement by DOE of the views expressed in this article.

– Does tiling soil attempt to remove unstable beam transverse impact ...

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Comparison of the 2-D *DRACO* Cross-Beam Energy Transfer (CBET) Simulations with OMEGA and NIF Experiments

J. A. Marozas, T. J. B. Collins, P. B. Radha, D. H. Edgell, D. H. Froula,
M. Hohenberger, F. J. Marshall, D. T. Michel, and W. Seka
Laboratory for Laser Energetics, University of Rochester,

The cross-beam energy transfer (CBET) effect causes pump and probe laser beams to exchange energy via stimulated Brillouin scattering,1 which tends to increase the scattered light, alter the time-resolved scattered-light spectrum, and redistribute absorbed laser energy. Reduced absorption and, consequently, reduced implosion velocity in symmetric direct-drive experiments on the OMEGA Laser System have been attributed to the CBET effect. Experimental measurements of the temporal evolution of the scattered-light spectra provides evidence for the CBET effect and is reproduced by *LILAC* simulations.2 The CBET effect has been incorporated into the 2-D hydrodynamics code *DRACO*3 as an integral part of the *Mazinisin* 3-D laser ray-trace package. Simulations using both *LILAC* and *DRACO* agree well with OMEGA direct-drive measurements (absorption fraction, shell trajectory, and scattered-light spectra) when the CBET effect is included in tandem with a nonlocal electron transport model or an equivalent heat-conduction model with a flux-limiter of 0.1. The polar-angle–dependent scattered-light measurement for OMEGA polar-drive (PD) experiments was reproduced using the CBET model in *DRACO*. There is an observed difference in the morphology of the imploding target on the first National Ignition Facility (NIF) PD shots; the shell is prolate without CBET compared to the oblate shells observed in the experiment. *DRACO* with the CBET model will be used to simulate the early NIF implosions.
This material is based upon work supported by the Department of Energy National Nuclear Security Administration under Award Number DE-NA0001944, the University of Rochester, and the New York State Energy Research and Development Authority. The support of DOE does not constitute an endorsement by DOE of the views expressed in this article.

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Nonlinear Interaction Between Multiple Incoherent Laser Beams in the Plasmas of Direct-Drive ICF *

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Laboratory for Laser Energetics, University of Rochester

In the direct-drive method of the inertial confinement fusion (ICF), the target is irradiated by multiple crossing laser beams. The coupling of laser energy to the plasma corona depends on the scattering of laser beams and the energy transfer between the beams.[1]

The laser beams driving ICF targets in experiments on the OMEGA and NIF Laser Systems are incoherent in space (as a result of distributed phase plates) and in time (because of smoothing by spectral dispersion and possibly multiple colors). The nonlinear interaction between multiple incoherent laser beams via low-frequency plasma response (in the ion-acoustic domain) has been studied using the non-paraxial model of wave propagation.[2]

Crossing laser beams are shown to generate common ion waves and to scatter off them, leading to an increase in the reflectivity. The scaling of reflectivity with the average laser intensity is determined by the interaction in high-intensity laser speckles. The results from the nonlinear laser–plasma interaction model are compared to the reduced model suitable for modeling cross-beam energy transfer (CBET) in hydrodynamic codes.[1]

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*This material is based upon work supported by the Department of Energy National Nuclear Security Administration under Award Number DE-NA0001944, the University of Rochester, and the New York State Energy Research and Development Authority. The support of DOE does not constitute an endorsement by DOE of the views expressed in this article.

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Cross-Beam Energy Transfer in Polar-Drive Implosions on OMEGA and the NIF

D. H. Edgell, T. J. B. Collins, V. N. Goncharov, I. V. Igumenshchev, J. A. Marozas, D. T. Michel, J. F. Myatt, P. B. Radha, W. Seka, and D. H. Froula
Laboratory for Laser Energetics, University of Rochester

Direct-drive experiments on the National Ignition Facility (NIF) require the use of the nonspherically symmetric indirect-drive beam layout. In polar drive (PD), the power and pointing of the cylindrically symmetric NIF beams are optimized to uniformly compress a capsule. As the beams refract and cross in the coronal plasma, cross-beam energy transfer (CBET) can cause laser energy to "bypass" the high-absorption region of the plasma near the critical surface.

Polar-drive experiments on both OMEGA using new phase plates optimized for PD and initial PD implosions on the NIF using the non-optimal indirect-drive phase plates have provided experimental evidence that the laser drive is different than predicted by hydrodynamic code modeling that does not include CBET. On the NIF the bang time is several hundreds of picoseconds later than predicted and the velocity of the imploding shell as measured by x-ray framing camera self-emission images shows that the target shell is not driven as fast as predicted. Measurements of the unabsorbed laser light during OMEGA PD implosions show that the total laser energy absorbed is significantly less than predictions not including CBET. The decreased performance is not uniform for all beams. Implosions predicted to be spherical when the effects of CBET are not modeled, are shown to be oblate, indicating that the beams offset to drive the target equator are affected the most. Spherical PD implosions have been achieved by increasing the relative beam power in the equatorial beams compared to the other more polar beams.

The effects of CBET are now incorporated into the 2-D hydrodynamics code *DRACO* and PD implosions on both OMEGA and the NIF can be modeled. Predictions will be compared with measurements for recent PD implosions on OMEGA where the laser intensity and the relative power in the different beam rings were varied.

*This material is based upon work supported by the Department of Energy national Nuclear Security Administration under Award Number DE-NA0001944, the University of Rochester, and the New York State Energy Research and Development Authority. The support of DOE does not constitute an endorsement by DOE of the views expressed in this article.

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Four Wave Mixing – a Death Star?*

E. A. Williams, D. E. Hinkel and C. A. Thomas
Lawrence Livermore National Laboratory

In NIF implosion experiments we routinely use cross-beam transfer (XBT) to transfer energy between the inner and outer cones of beams as a tool to control the symmetry of the implosion. The inner and outer laser cones of beams are tuned to different wavelengths. Ion waves are resonantly excited inside the hohlraum plasma, in the beam crossing region, wherever the required matching condition is satisfied – namely that the beat wave between the beams, Doppler shifted to the plasma frame matches the local ion acoustic dispersion relation. In this region of plasma, energy is scattered from the higher to the lower frequency (in the rest frame) laser beam by the ion wave grating created by the laser beams' beat ponderomotive force [1].

With 96 beams incident through each laser entrance hole, a large number (96*95/2) of possible gratings are created. Here we investigate the possibility that some third beam could scatter off the ion wave created by an initial pair. The k-matching conditions apply stringent conditions on the beam geometry (directions). The frequency matching condition is automatically satisfied because the fourth scattered wave is unconstrained in frequency.

The process has been called Brillouin Enhanced Four Wave Mixing (BEFWM) and has been experimentally observed in a simpler planar geometry [2].

We show that the NIF beam geometry allows for such a process, in which for instance, the ion wave created in the overlap of a 23 and a 50 degree beam can scatter a third 44 degree beam. The resulting new beam, created by the BEFWM process emerges from the crossing volume, propagating at approximately 8 degrees to the hohlraum axis, impinging on the capsule.

A simplified model shows that in the worst case about 7% of the 44 degree beam energy could be scattered.

This is more than enough to impact capsule symmetry in the first picket, before the capsule has developed a protective layer of plasma blow-off. The potential impact appears lower in the main pulse, even though the scattered energy is larger, for this reason.

1. P. Michel et al. Phys. Plas. **16**, 042702 (2009) and references within
2. C. W. Domier and N. C. Luhmann, Phys. Rev. Lett. **69**, 3499 (1992)

* This work was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344.

43rd Annual Anomalous
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The Quartraum: A platform for investigation of cross-beam energy transfer*

D. E. Hinkel, M. B. Schneider, M. D. Rosen, and E. A. Williams
Lawrence Livermore National Laboratory

Cross-beam energy transfer [1] is a methodology used at the National Ignition Facility (NIF) to control implosion symmetry, by transferring energy between the inner and outer cones of laser beams. This process is time-dependent, and does not transfer power in a spatially uniform manner. A platform to investigate the spatial non-uniformity of laser beams after having undergone cross-beam energy transfer is under development. This target consists of the slice of the hohlraum near the laser entrance hole (LEH), where transfer occurs, which is roughly one-fourth the length of a nominal hohlraum (quartraum). Beams are incident on this LEH from only one side of the quartraum. The outer beams hit the quartraum cylindrical walls, and the inner beams hit the far endcap of the cylinder. This far endcap is either a 100% LEH window that the inner beams burn through (and then strike a witness plate), or it is a thin wall that is imaged. Stretch goals for this platform are detection of specularly reflected outer beams, or of Brillouin Enhanced Four-Wave Mixing [2].

[1] P. Michel *et al.*, Phys. Plasmas **16**, 042702 (2009), and references therein.

[2] E. A. Williams *et al.*, this conference.

* This work was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344.

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Laser-plasma interaction and beam crossing effects

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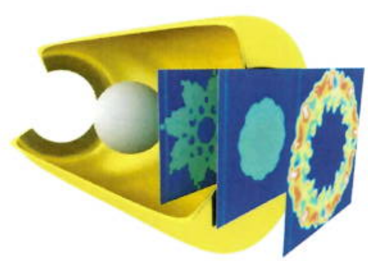
Laser beam crossing effects are an important issue for ICF. Fifteen years ago, these effects have been studied both theoretically[1] and experimentally[2] in simple configurations. Today, in the current ICF target designs, many beams may overlap each other. Accordingly, the first models based on a two-beam energy transfer are not very satisfactory and models including more physics[3] or models based on multi-beam interactions seem more appropriate.[4,5]

In order to study the energy transfer in centimetric hohlraums irradiated by many crossed beams, we are developing a post-processor, SECHEL, which uses data given by the hydro code FCI2. As a first step, we are implementing a steady-state model very similar to the LLNL model[4] in SECHEL. We will show some results given by this post-processor using the data from an indirect drive ICF experiment. We will examine the range of validity of this model. More specifically, the steady-state hypothesis will be questioned. Missing physics and possible improvements will be investigated.



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2. R. K. Kirkwood *et al.*, PRL (1996), K. B. Wharton *et al.*, PRL (1998), C. Labaune *et al.*, PRL (1999, 2000)
3. S. Hüller and D. Pesme (unpublished, 2009)
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Current Filaments, Plasma Flow and their Spontaneous Fields in Laser-Hohlraum Interactions*

C. K. Li,[1] F. H. Séguin,[1] J. A. Frenje,[1] R. D. Petrasso,[1] P. A. Amendt,[2] O. L. Landen,[2] S. C. Wilks,[2] R. Betti,[3] J. P. Knauer,[3] D. D. Meyerhofer,[3] J. M. Soures,[3] J. D. Kilkenny,[4] M. Farrell,[4] and A. Nikroo[4]
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[2]*Lawrence Livermore National Laboratory, Livermore, CA 94550 USA*
[3]*Laboratory for Laser Energetics, University of Rochester, Rochester, NY 14623 USA*
[4]*General Atomics, San Diego, CA, 92186 USA*

A hohlraum is a high-Z enclosure which creates an environment filled with nearly blackbody (Planckian) radiation when irradiated by high-power lasers. Understanding the structure and dynamics of plasmas in the hohlraum, and the electromagnetic fields the plasma generates, is critical to studies of inertial-confinement fusion and high-energy-density physics because hohlraums have been widely used as radiation sources or platforms for a large variety experiments. We have been doing a series of experiments to systematically address various issues in hohlraum dynamics. We report in this talk the first time-gated, side-on proton radiography that reveals the structures and dynamics of current filaments, plasma flow and their spontaneous electromagnetic fields occurring at the hohlraum laser-entrance holes. Plasma instabilities are shown to play critical roles in such dynamic structures: in the earlier times with collisionless Weibel-induced current filaments resulting from expansion of low-density plasma into vacuum, and in the later times with resistive magnetohydrodynamic modes resulting from the adiabatic expansion of on-axis, stagnated wall plasma blowoff. Time-resolved observations of spontaneous electromagnetic fields associated with these plasma instabilities have been made. The experiments demonstrate the dominance of magnetic fields over electric fields, consistent with self-emissions of charged fusion products observed from ignition-scale hohlraums in experiments at the National Ignition Facility and energy-scaled hohlraums in experiments at OMEGA laser facility. These experiments provide important insight into the basic physics of the interplay between the magnetic fields and plasma flow, as well as into hohlraum dynamics.

*This work was supported in part by US DOE and LLE National Laser User's Facility, LLNL, LLE, FSC, and General Atomics.

Oral presentation is preferred

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Optimizing Hohlraum Performance via Case-to-Capsule Ratio for Inertial Confinement Fusion

J. L. Kline,[1] D. A. Callahan,[2] D. E. Hinkel,[2] E. Storm,[2] D. C. Wilson,[1] A. Simakov[1], A. Yi,[1] and J. D. Moody[2]
[1]Los Alamos National Laboratory
[2]*Lawrence Livermore National Laboratory*

One of the key issues with ignition hohlraum performance in terms of laser coupling is the propagation of the inner cone beams. Most of the backscattered laser light due to laser plasma instabilities comes from these beams primarily in the form of Stimulated Raman Scattering (SRS). This prevents the inner cone laser beams from depositing their energy into the hohlraum wall near the equatorial plane. As a result, large amounts of energy from the outer cone beams must be redirected via cross beam energy transfer to the inner cone beams to produce symmetric capsule implosions. One cause of the poor propagation of these beams is the volume between the capsule and hohlraum wall is filled with blow off plasma from both items leading to high density plasmas in the region that generates large SRS growth rates. One potential way to reduce the SRS backscatter, as well as improve the implosion symmetry is to increase the separation between the capsule and the wall. The concept is that the volume and the distance between the laser and capsule increases reducing SRS and improving the propagation of the inner cone beams to the hohlraum wall. In addition, a smaller capsule averages the incident xray flux from a larger area of the hohlraum wall. This smoothes the radiation pattern hitting the capsule leading to more symmetric implosions. In this presentation, these effects will be examined for hohlraums with smaller capsules to determine how these effects scale with variation in the case-to-capsule ratio.

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A review of crossed-beam energy transfer*

P. Michel
Lawrence Livermore National Laboratory

Cross-beam energy transfer (CBET) is a process where the refractive index modulation imprinted in a plasma by the beat wave between overlapping laser beams can act as a Bragg diffraction grating, and scatter energy from one laser beam into another one [1]. CBET can occur in any ICF or HEDP experiment where intense laser beams ($I>10^{13}$ W/cm^2) overlap in plasmas, and can have dramatic effects on laser energy coupling to the target [2], irradiation symmetry [3], backscatter levels [4] etc.

In this presentation, we will review recent progress towards modeling, measuring and controlling CBET. Recent modeling efforts have focused on laser-plasma interactions (LPI) packages implementation in hydrodynamics codes, where LPI and hydrodynamics are treated self-consistently. New measurements of CBET in indirect-drive experiments at NIF, and CBET mitigation strategies for direct-drive experiments at Omega will also be presented.

1. W.L. Kruer, S.C. Wilks, B.A Afeyan & R.K. Kirkwood, Phys. Plasmas **3**, 1 (1996)
2. D. Froula, I.V. Igumenshchev, D. T. Michel et al., Phys. Rev. Lett. **108**, 125003 (2012)
3. P. Michel, L. Divol, E.A. Williams et al., Phys. Rev. Lett. **102**, 025004 (2009)
4. J.D. Moody, P. Michel, L. Divol et al., Nature Physics **8**, 344 (2012)

* This work was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344.

❖ Morning Session ❖
Stevenson Ballroom B

9:00 AM	Two-Plasmon Decoy
11:30 AM	Business Meeting

❖ Evening Session ❖
Stevenson Ballroom B

7:30 PM	A review of two-plasmon decoy W. Seka, LLE
8:00 PM	Discussion Section: Two-Plason Decoy W.L. Kruer, UCD

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1% hots at 1.1×10^{15} W/cm²

Measurements of the Divergence of Fast Electrons in Laser-Irradiated Spherical Targets*

A. A. Solodov, B. Yaakobi, J. F. Myatt, J. A. Delettrez, C. Stoeckl, and D. H. Froula
Laboratory for Laser Energetics, University of Rochester,

Need < .1% laser energy coupled to unablated shell

In recent experiments using directly driven spherical targets, the energy in fast electrons was found to reach ~1% of the laser energy at an irradiance of $\sim 1.1 \times 10^{15}$ W/cm². The fraction of the fast electrons absorbed in the compressed fuel shell depends on their angular divergence. In this experiment, divergence is deduced from a series of shots where Mo-coated shells of increasing diameter (D) were embedded within an outer CH shell. The intensity of the Mo-K_α line and the hard x-ray radiation were found to increase approximately as $\sim D^2$, indicating wide divergence of the fast electrons. Alternative interpretations of these results (electron scattering, radiation excitation of K_α, and an electric field caused by return current) are shown to be unimportant. The transport of fast electrons, Mo-K_α, and the hard x-ray emission were modeled using the *EGSnrc* Monte Carlo code.

This material is based upon work supported by the Department of Energy National Nuclear Security Administration under Award Number DE-NA0001944, the University of Rochester, and the New York State Energy Research and Development Authority. The support of DOE does not constitute an endorsement by DOE of the views expressed in this article.

* Data for planar + 60 beam [illegible] ≤ 1.1×10^{15} W/cm²
Can get 1% in 50–100 keV

→ ~1/4 of hots absorbed by target
produced at $n_{cr}/4$

Hots produced at end of laser pulse when plasma scale length is large

Omega vs NIF pulse lengths ? →

1 atm N_2

Moly Ball Expt 1ns 50μ CH 26kJ 1.1×10^{15} W/cm²

Hot e transport EGSnrc code Kawrakow paper Medical Physics

Hots produced after > .5 ns of 1 ns pulse

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Ultraviolet Thomson Scattering from Two-Plasmon–Decay Driven Electron Plasma Waves at Quarter-Critical Densities

R. K. Follett, D. T. Michel, S. X. Hu, R. J. Henchen, J. Katz, and D. H. Froula
Laboratory for Laser Energetics, University of Rochester,

Thomson scattering is used to probe electron plasma waves (EPW's) driven by the two-plasmon–decay (TPD) instability near quarter-critical density. TPD-driven EPW's were observed at densities consistent with the common-wave TPD model. Five laser beams ($\lambda 3\omega$ = 351 nm) produced 600-μm-diam laser spots with overlapped intensities up to 3 • 10^{14}. The planar targets were 30-μm-thick molybdenum coated with 30 x 10^{14} W/cm^2. of CH. The K*a* yield from molybdenum was used to infer the fraction of laser energy converted into hot electrons. A 263-nm Thomson-scattering beam was used to probe at densities ranging from 0.18 to 0.26 *n*c, where *n*c is the critical density for 351-nm light. The experimental geometry was chosen to match the five-beam TPD common wave *k* vector.1 The Thomson-scattering spectrum shows a large amplitude, narrow (~1.6-nm FHWM) feature centered around 423.4 nm. This wavelength corresponds to scattering from EPW's with a normalized wave vector $k/k3\omega$ = 1.3, a density of $n_{e}/n_{c}=0.243$, and a temperature of *T*e = 1.6 keV. The maximum growth rate for the five-beam common plasma wave with *k*c = 1.3 k3ω is predicted to occur at $n_{e}/n_{c}=0.243$, where k_c is the *k* vector with an angle of 22.3° from each beam.[2] This angle is within the *f* number of the drive beams.

This material is based upon work supported by the Department of Energy National Nuclear Security Administration under Award Number DE-NA0001944, the University of Rochester, and the New York State Energy Research and Development Authority. The support of DOE does not constitute an endorsement by DOE of the views expressed in this article.

1. C. Stoeckl *et al.*, Phys. Rev. Lett. **90**, 235002 (2003).
2. D. T. Michel *et al.*, Phys. Rev. Lett. **109**, 155007 (2012).

43rd Annual Anomalous Absorption Conference
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Stimulated Raman and Brillouin backscatter as a remote laser power sensor in high-energy-density plasmas*

J. D. Moody, D. J. Strozzi, L. Divol, P. Michel, H. F. Robey, S. LePape, J. Ralph, J. S. Ross, S. H. Glenzer,[1] R. K. Kirkwood, O. L. Landen, B. J. MacGowan, A. Nikroo,[2] and E. A. Williams

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Stimulated Raman and Brillouin backscatter (SRS and SBS) are used as remote sensors to quantify the instantaneous laser power after transfer from outer to inner cones that cross in a National Ignition Facility (NIF) gas-filled hohlraum plasma. By matching SRS and SBS between shots reducing outer vs shots reducing inner power we infer that ~ half of the incident outer-cone power is transferred to inner cones, for the specific time and wavelength configuration studied. This is the first instantaneous non-disruptive measure of power transfer in an indirect drive NIF experiment using optical measurements. These results are comparable to transfer estimates from time-averaged symmetry measurements.

* This work was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344.

Energy transferred to

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Absolute Threshold of Two-Plasmon Decay Driven by Multiple Laser Beams

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

D. F. DuBois
Los Alamos National Laboratory and Lodestar Research Corporation

D. A. Russell
Lodestar Research Corporation, Boulder, CO

H. X. Vu
University of California at San Diego

A three-dimensional Zakharov model (*ZAK3D*) of the two-plasmon–decay (TPD) instability[1,2] is used to determine the absolute threshold for multiple coherent, overlapping laser beams. It was found that multiple beams can cooperate to generate absolute growth; therefore, the absolute threshold is lower than that predicted by single-beam theory.[3] Three different beam geometries are investigated in four-beam simulations and the threshold for the onset of absolute instability is found to depend on the specific geometry, including polarization.

Nonlinear saturation of the absolute instability is investigated with *ZAK3D* to determine the importance of these absolute modes over long (hydrodynamic) times. The connection with recent multibeam TPD experiments[4] is discussed.

This material is based upon work supported by the Department of Energy National Nuclear Security Administration under Award Number DE-NA0001944, the University of Rochester, and the New York State Energy Research and Development Authority. The support of DOE does not constitute an endorsement by DOE of the views expressed in this article.

1. D. F. DuBois, D. A. Russell, and H. A. Rose, Phys. Rev. Lett. **74**, 3983 (1995).
2. D. A. Russell and D. F. DuBois, Phys. Rev. Lett. **86**, 428 (2001).
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The Effects of Beam Geometry and Polarization on Two-Plasmon Decay Driven by Multiple Laser Beams

R. W. Short, J. F. Myatt, and J. Zhang
Laboratory for Laser Energetics, University of Rochester

It is now well established that for direct-drive geometries, two-plasmon decay (TPD) is a collective process in which a given set of decay waves is driven by several laser beams.1,2 The single-beam decay is maximized on a *k*-space hyperbola lying in the beam's plane of polarization so that maximum convective gain for the multibeam process occurs near the intersection of the hyperbolas, corresponding to the beams involved. All the hyperbolas intersect at the origin in *k*-space, so TPD tends to be most strongly driven in this small-*k* region. Depending on beam orientation and polarization, the second branches of the hyperbolas may or may not also intersect at a larger value of *k*. However, the instability can only be convective in this large-*k* region, whereas it can be absolute in the small-*k* region, and in fact it is found that the absolute threshold for TPD is in general lower than the convective threshold. Therefore, the small-*k* absolute instability is expected to dominate the linear phase of TPD growth, consistent with Zakharov simulations.3 Results for the absolute TPD threshold as a function of beam geometry and polarization will be presented, and the consequences for direct-drive experiments will be discussed.

1. C. Stoeckl *et al.*, Phys. Rev. Lett. **90**, 235002 (2003).
2. D. T. Michel *et al*, Phys. Rev. Lett. **109**, 155007 (2012).
3. J. Zhang *et al*, this conference.

* This work was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344.

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Measurement of Long-Scale-Length Plasma Density Profiles Using Refractometry

D. Haberberger, D. H. Edgell, S. X. Hu, S. Ivancic, R. Boni, and D. H. Froula
Laboratory for Laser Energetics, University of Rochester,

An accurate understanding of the plasma conditions near quarter critical density is important in quantifying the hot electrons generated by two-plasmon decay in long-scale-length plasmas (>100 μm). The hot-electron production has been shown to be a strong function of $I_q L_q / T_q$, where I_q is the laser intensity, L_q is the plasma scale length, T_q is the electron temperature, and "q" denotes the condition at quarter critical.

A series of experiments was performed using the four UV (351-nm) beams on OMEGA EP that varied the density scale length at quarter critical by changing the radius of curvature of the target while maintaining a constant laser intensity ($I_L \sim 5 \times 10^{14}$ W/cm^2) and electron temperature ($T_e \sim 2.25$ keV). This allowed for a unique set of conditions where the dependence of the fraction of laser energy converted to hot electrons, f_{hot}, on plasma scale length is isolated. Despite keeping a relatively constant I_L and T_e, f_{hot} was observed to increase from 0.005% to 1% by increasing the diameter of the target from 450 μm to 4000 μm. Over the range of target diameters used, f_{hot} was observed to vary exponentially with the plasma scale length, which increased from 95 μm to 240 μm.

The plasma density scale length near quarter-critical density is typically obtained through hydrodynamic simulations. Standard interferometry techniques used to measure these long-scale-length plasmas are hindered by the large amount of phase accrued by the probe pulse. To address this issue, a new diagnostic was developed based on refractometry using angular spectral filters. The diagnostic measures the refraction angles of a 10 ps, 4ω (263 nm) probe laser after propagating through the plasma. An angular spectral filter is used in the Fourier plane of the probe beam where the refractive angles of the rays are mapped to space, allowing for filtering of certain angular components. Upon returning to the image plane, shadows of the filter are present. The edges of the filter represent a contour of constant refraction angle. These contours are used to infer the phase of the probe beam, which are used to calculate the plasma density profile.

This material is based upon work supported by the Department of Energy National Nuclear Security Administration under Award Number DE-NA0001944, the University of Rochester, and the New York State Energy Research and Development Authority. The support of DOE does not constitute an endorsement by DOE of the views expressed in this article.

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Current experimental and theoretical understanding of the two-plasmon decay instability*

W. Seka, J.F. Myatt, J. Zhang, R.W. Short, D.H. Froula, D.T. Michel, A. Maximov, and V.N. Goncharov, I.V. Igumenshchev, *LLE, University of Rochester*, D.F. DuBois, D.A. Russell,– *Lodestar, Boulder, CO*, and H.X. Vu, – *University of California, San Diego, CA.*

Recent LLE experimental evidence in the form of time-resolved $\omega/2$ spectra has shown that the TPD instability starts from the absolute instability at $n_c/4$ and rapidly extends throughout the region between $n_c/4$ and the Landau cutoff (typically $n_c/5$). The rapid evolution entails density gradient modifications and is highly nonlinear preventing the observation of the linear convective TPD instability. The TPD instability is now recognized as a multi-beam instability based on experiments and PIC, RPIC, Zakharov simulations and theory. All of these simulations are in reasonable agreement but Zakharov simulations allow longer runs under many different plasma conditions and extension to three dimensions. Our observations support the results of these simulations.

*This work was supported by the U.S. Department of Energy Office of Inertial Confinement Fusion under Cooperative Agreement No. DE-FC52-08NA28302, the University of Rochester, and the New York State Energy Research and Development Authority. The support of DOE does not constitute an endorsement by DOE of the views expressed in this article.

❖ Morning Session ❖
Stevenson Ballroom B

9:00 AM	Rad-Hydro and LPI
12:10 PM	Discussion Section: Rad-Hydro and LPI M.J. Schmitt
1:00 PM	Adjourn

❖ Evening Session ❖
Skamania Lodge Garden Patio

7:00 PM	Working Business Dinner

Investigating spatio-temporal laser energy deposition and its effects on implosion symmetry

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Hydrodynamic modeling of gold bubble expansion and laser-plasma interaction in mm-long gas-filled hohlraums experiments on the LIL facility

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Several laser-plasma interaction (LPI) campaign have been conducted using gas-filled hohlraums on the LIL facility, which is a prototype of one quadruplet of the upcoming french laser megajoule (LMJ). Different targets have been designed: one relevant to the gold bubble expansion seen by the outer beams in ignition hohlraum, which could be sensitive to the stimulated Brillouin scattering (SBS), and one relevant to the inner beams with long distance of propagation and sensitive to the stimulated Raman scattering (SRS).

The first configuration consists of 3mm long target where the laser interacts with a plasma first composed of pentane, then of gold coming from the wall expansion which has been imaged. This setup, with 6ns pulse long and a maximum energy of 15kJ, allows us to study in detail the gold bubble expansion that occurs in ignition hohlraum and in particular to model it with hydro-radiative simulations and variations in thermal conduction and atomic physics models.

The second configuration consists of 4mm and 1.5mm long target where the laser beam propagates into an under-critical pentane plasma, that fills a gold cylinder. This second setup which has been done with the same laser pulse and energy as the first one but with variation on the optical smoothing techniques, is relevant for the study of SRS.

We will present and discuss hydrodynamic calculations together with experimental results of the LPI campaign. Calculated spectra will be compared to experimental results and discussed with results from paraxial simulations carried out with the code HERA.

– High adiabat ID platforms for implosion studies

Intermediate

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Indirect-drive exploding pusher on the NIF: a (almost) one-shock-system for ICF physics studies*

L. Divol[1], S. Le Pape[1], L. Berzak Hopkins[1], D. Casey[1], A. Zylstra[2], M. Rosenberg[2], M. Gatu-Jonson[2], J. Frenje[2], R. Bionta[1], J. Mcnaney[1], T. Ma[1], B. Kauffman[1], J. Kilkenny[3], R. Petrasso[2], J. Lindl[1], J. Edwards[1], W. Hsing[1], N. Meezan[1], A.J. Mackinnon[1]

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2-Plasma Science and Fusion Center, Massachusetts Institute of Technology, Cambridge, MA, USA
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The indirect Drive Exploding Pusher (IDEP) is a new experimental platform fielded on the National Ignition Facility to study many aspects of indirect drive ICF in a simplified configuration. The driver is a low pressure He-fill (17 Torr) hohlraum that minimizes the role of Laser-Plasma interaction: the measured laser/hohlraum coupling efficiency was 99% while simulations predict negligible Cross Beam Energy Transfert (CBET). The capsule is a thin (120 μm) Si-doped plastic capsule filled with 40 atm (STP) of DD or DT gas. The laser pulse is tuned to drive one strong symmetric convergent shock through the gas, while compressing it by > 100 x (convergence ratio of 5x). The rebounding shock heats 0.5 g/cc DT to > 4 keV, yielding 5 10^14 neutrons (Yield Over Clean is essentially 100%). As the compressed core is large (100-200 μm radius) and the burn history long (> 300 ps), this platform allows for detailed spatio-temporal measurements with existing diagnostics. Detailed comparison of measurements and simulations will be presented. For X-rays, we will discuss details of the X-ray drive (~ 290 eV), symmetry (< 1% out of round), bang time and details of time resolved X-ray images. For nuclear diagnostics, we will use 2 companion shots (DD and DT at same atomic number density) to discuss yields, burn temperatures, areal densities of fuel and ablator, burn history and symmetry.

* This work was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344.

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Low-Density Gas-filled Hohlraums: A platform to study hohlraum physics models that is intermediate between Au Spheres and Ignition Hohlraums *

M. D. Rosen, D. Callahan, D. Hinkel, P. Amendt, L. Berzak Hopkins, and J. Edwards
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The current hohlraum physics model, the "High Flux Model" (HFM)[1] was motivated by results from 3 platforms: 1) Au sphere x-ray emission experiments performed at the URLLE Omega laser in 2005; 2) Vacuum hohlraum x-ray emission at the National Ignition Facility (NIF) in 2009; and 3) Analysis of the capsule implosion symmetry and Raman Stimulated Backscatter spectra from many full scale ignition experiments. While the capsule drive in platform #3 seems to be ~ 15% less than predicted, the HFM performed quite well in predicting the drive on platforms #1 and #2.

In order to try to understand these results, we propose here to further study the transition from platform #2 to #3 by using low density gas filled hohlraums on NIF. The predicted x-ray emission differences between models would be nearly as dramatic as those of the vacuum hohlraums, and can thus serve as a launching point to a variety of excursions from that platform towards the full ignition hohlraum.

We discuss here the analysis and design of this platform, ideas for the excursions therefrom, and diagnostics that would be very helpful in this pursuit. Trying to untangle gas fill effects vs. pulse length effects will also be discussed.

1. M. D. Rosen, H. A. Scott, D. E. Hinkel, *et al.*, HEDP 7, 180 (2011).

* This work was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344.

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Including Mix models

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A 1D Hot Spot Mix Model for Diagnosing Performance of NIF Ignition Experiments*

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We report results of research in which we match key observables, neutron yield, ion temperature, aerial density, for several NIF ignition experiments using spherically symmetric post-shot simulations with mix models. We use a programmable mix model that prescribes a material and energy mix history profile (i.e. material depth to mix as a function of time) at both the fuel-ablator and gas-fuel interfaces. Scanning over many hundreds of possible mix histories, we find specific solutions that simultaneously satisfy at least these three. This has been done for five different NIF ignition shot experiments.

The nature of the mix solutions we find indicates that the performance degradation of ignition shots on the NIF is primarily due to fingers of cold DT fuel penetrating deeply into the hot spot. Also, a Richtmyer-Meshkov instability induced component of mixing at the fuel-ablator interface is implied. We will discuss how this work points us toward ways to improve our ability to directly simulate these capsule implosions as well as ways of improving the performance of these capsules on the NIF.

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Hohlraum Gas fill effects on implosions

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NIF Hohlraum Experiments at Room Temperature

D. J. Strozzi, D. E. Hinkel, J. E. Ralph, T. Ma,
D. A. Callahan, J. L. Kline, J. D. Moody
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The first energetics experiments in 2009 at the National Ignition Facility utilized sub-scale targets, the first two of which were fielded at room-temperature ("warm") instead of cryogenic conditions used for all subsequent shots. Due to limits on the pressure the hohlraum window can hold, the warm shots used neopentane (C_5H_{12}) as the hohlraum gas fill. Cryogenic shots initially used H_4He but quickly switched to pure He, which has been used since.

We have recently conducted a series of warm hohlraum experiments on NIF, in full-scale targets but with sub-ignition (up to 1.3 MJ) laser energies. This allows us to revisit the role of hohlraum gas composition in hohlraum coupling. Of particular interest is differences in x-ray drive, backscatter, implosion symmetry, and inner beam propagation to the hohlraum wall.

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Simulations of direct drive targets on Omega and NIF*

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Simulations using the HYDRA code[1] have been performed of direct-drive gas-filled CH capsules to examine the temperature dependence of the inner surface of the capsule where mix occurs. Various spectral tracers, doped into the inner layer of the capsule, are examined for their effect on capsule implosion characteristics and their ability to provide spectral signatures that can be used to infer the location, temperature and electron density of the mix region of the capsule. Simulations results will be shown including the effect of drive energy on heating of the shell near the gas-shell interface.

1. M. M. Marinak, R. E. Tipton, O. L. Landen, T. J. Murphy, P. Amendt, S. W. Hann, S. P. Hatchett, C. J. Keane, R. McEachern, and R. Wallace, Phys. Plasmas 3, 2070 (1996).
2. M. J. Schmitt, et al., Phys. Plasmas **20**, 056310 (2013).

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❖ Morning Session ❖
Stevenson Ballroom B

9:00 AM	Kinetic Effects
11:10 AM	Discussion Section: Kinetic Effects F. Tsung, UCLA
12:00 PM	Adjourn

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Shock-driven resistive heating in mixed species thermonuclear fuels*

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The measurement of strong, self-generated electric fields (~1-10 GVolts/m) in imploding capsules [1] has led to a growing interest in the potential role of species separation and kinetic effects in inertial-confinement-fusion (ICF) thermonuclear fuels [2]. In particular, the arranged sequence of (4) shocks in a central-hot-spot ICF target may lead to transient species separation of the deuterium (D) and tritium (T) across each shock front as the DT fuel is traversed. The process of species separation involves interpenetration of each fuel species, resulting in a drift velocity that can lead to increased entropy generation from resistive and diffusive heating across and behind the shock front. Estimates of the degree of dissipation energy following four-shock traversal of the main fuel give almost 100 Joules, which may impact ignition performance margins. The same mechanisms for elevated shock heating are analytically applied to the ~2x neutron anomaly seen on Omega implosion experiments using equimolar mixtures of D and ^{3}He [3]. The physical picture consists of anomalously heated post-shock fuel before deceleration onset, leading to reduced stagnation pressure and a lowered yield. This scenario is also applied to hot-spot formation with DT ignition experiments on the NIF following "shock flash", where greater shock heating of the DT gas may also lead to a reduced stagnation pressure - as experimentally inferred.

[1] J.R. Rygg *et al.*, Science **319**, 1223 (2008); C.K. Li *et al.*, Phys. Rev. Lett. **100**, 225001 (2008).
[2] P. Amendt, C. Bellei and S.C. Wilks, Phys. Rev. Lett. **109**, 269502 (2012); G. Kagan and X.Z. Tang, Phys. Plasmas 19, 082709 (2012); O. Larroche, Phys. Plasmas **19**, 122706 (2012); C. Bellei, P. Amendt, S.C. Wilks et al., Phys. Plasmas **20**, 012701 (2013); O. Larroche, Phys. Plasmas **20**, 044701 (2013); C. Bellei, P. Amendt, S.C. Wilks et al., Phys. Plasmas **20**, 044702 (2013).
[3] J.R. Rygg et al., Phys. Plasmas 13, 052702 (2006).

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Validation of LSP Hybrid Fluid and Kinetic Plasma Shock Simulations*

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The propagation of shocks in plasmas is typically studied in one of two limiting cases. The first case is where the plasma is sufficiently collisional that the fluid approximation holds. This is essentially (when a B-field is not included) the case of standard fluid hydrodynamics, and is currently used in radiation hydrodynamics codes used in the ICF and HEDP communities. The second case is when the plasma is collisionless. In this case, the particles interact via their electric charge. Plasma shock waves in collisional plasmas contain components of both of these limiting cases. Not only is there a well-defined ion shock region, of the order of an ion-ion mean free path, but because the plasma consists of charged particles, there is also an electric field present. This was first investigated in a seminal paper by Jaffrin and Probstein (J&P) [1], and more recently by Bellei et al. [2] and Larroche [3]. We have benchmarked the code LSP, [4] in both the Particle-In-Cell (PIC) and fluid modes, against the results of J&P. In the low Mach number limit ($M < 2$) both fluid and kinetic approaches agree with the analytic results in J & P. However, in the high Mach number limit, the kinetic case diverges from both the fluid case and the J&P result. It appears that for high Mach number, the approximations made in the analytic work of J&P break down. Based on the PIC simulations, this is due to kinetic effects, such as reflection of the ions at the shock front [5]. Finally, we discuss the implications of this work as it pertains to studying kinetic and species separation effects in hot spot ignition.

[1] Jaffrin and Probstein, Physics of Fluids **7**, 1658 (1964)
[2] C. Bellei, P. Amendt, S.C. Wilks et al., Phys. Plasmas **20**, 012701 (2013)
[3] O. Larroche, Phys. Plasmas **19**, 122706 (2012)
[4] D. R. Welch, et al., Nucl. Instrum. Methods Phys. Res. A **464**(1–3), 134–139 (2001).
[5] C. Bellei, P. Amendt, S.C. Wilks et al., Phys. Plasmas **20**, 044702 (2013).

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Ion reflection at shock fronts: implications for mix*

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Shock waves that propagate in collisional plasmas may exhibit characteristics of collisionless systems, with part of the upstream ion flow being reflected at the shock front by the self-consistent electric field [1].
When these shocks propagate across an interface that separates different materials (such as an ablator-gas interface), this mechanism can push some high-Z ions from the ablator into the gas region. In this talk we will discuss under which conditions this effect occurs and what are the implications for mix in ICF implosions.

[1] C. Bellei, P. Amendt, S.C. Wilks et al., Phys. Plasmas **20**, 044702 (2013).

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Multi-species effects in inertially confined plasmas*

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Inertial confinement fusion (ICF) implosions are routinely modeled with single-fluid codes. Individual dynamics of the fuel constituents is not resolved; only the overall pressure, density and fluid velocity are evolved, though electron and ion temperatures are often distinguished. An obvious weakness of such an approach is impossibility to predict relative concentrations of multiple ion species that are to undergo fusion reactions.

Multi-fluid plasma formalism, consistently capturing the physics behind and consequences of the relative motion of ion species, is presented. Implications for the ICF implosions are discussed.

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A Comparison of Stopping Power Theories with Results from Particle-in-Cell and Molecular Dynamics Codes*

Ian N. Ellis[a,b], Frank R. Graziani[a], David J. Strozzi[a], Michael P. Surh[a], Viktor K. Decyk[b], Frank S. Tsung[b], and Warren B. Mori[b]
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[b]*University of California, Los Angeles, California, USA*

The effect of correlated electron stopping on Fast Ignition is an open question. In this process, the wake produced by an electron modifies the dynamics and stopping power of the electrons that travel behind it.[1,2] Particle-in-Cell (PIC) codes are a useful tool to study the process. However, if small impact collisions are important, then single-particle stopping power in PIC codes will depend on the details of the particle shape and size (and interpolation function and cell size). Therefore, to determine the impact of correlation effects on electron stopping, we need to establish single-particle baseline stopping power in PIC simulations. In this poster, we present stopping power results from UCLA PIC codes and the large-scale molecular dynamics code ddcMD and compare them with various theories of stopping power, including the Bohr formula and the random phase approximation. We also propose modifications to the theories to take into account finite-size particles and compare the modified theories with the PIC simulation results.

1. C. Deutsch and P. Fromy, "Correlated stopping of relativistic electrons in superdense plasmas," *Physics of Plasmas* **15**, 3597 (1999).

2. A. Bret and C. Deutsch, "Correlated stopping power of a chain of N charges," *Journal of Plasma Physics* **74**, 595 (2008).

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Vlasov-Fokker-Planck modeling of High-Energy-Density Plasmas *

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University of California Los Angeles

Vlasov-Fokker-Planck simulations can be applied to a wide variety of problems in High-Energy-Density Plasmas. They can be used with an explicit solver to study the physics of waves in plasma media, including Landau Damping, echoes, instabilities etc., just like standard Vlasov codes. Moreover, they allow us to study the effect of collisions on these kinetic phenomena. On the other had, using an implicit solver, they enable kinetic simulations of realistic temporal and spatial scales. Recent simulations with the VFP code OSHUN [1,2] will be presented for all of the aforementioned problems. The algorithmic improvements that have facilitated these studies will be also be discussed.

[1] M. Tzoufras, A.R. Bell, P.A. Norreys, F.S. Tsung, JCP 230 (17), 6475-6494 (2011)
[2] M. Tzoufras, A. Tableman, F.S. Tsung, W.B. Mori, A.R. Bell, Phys. Plasmas 20, 056303 (2013)

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