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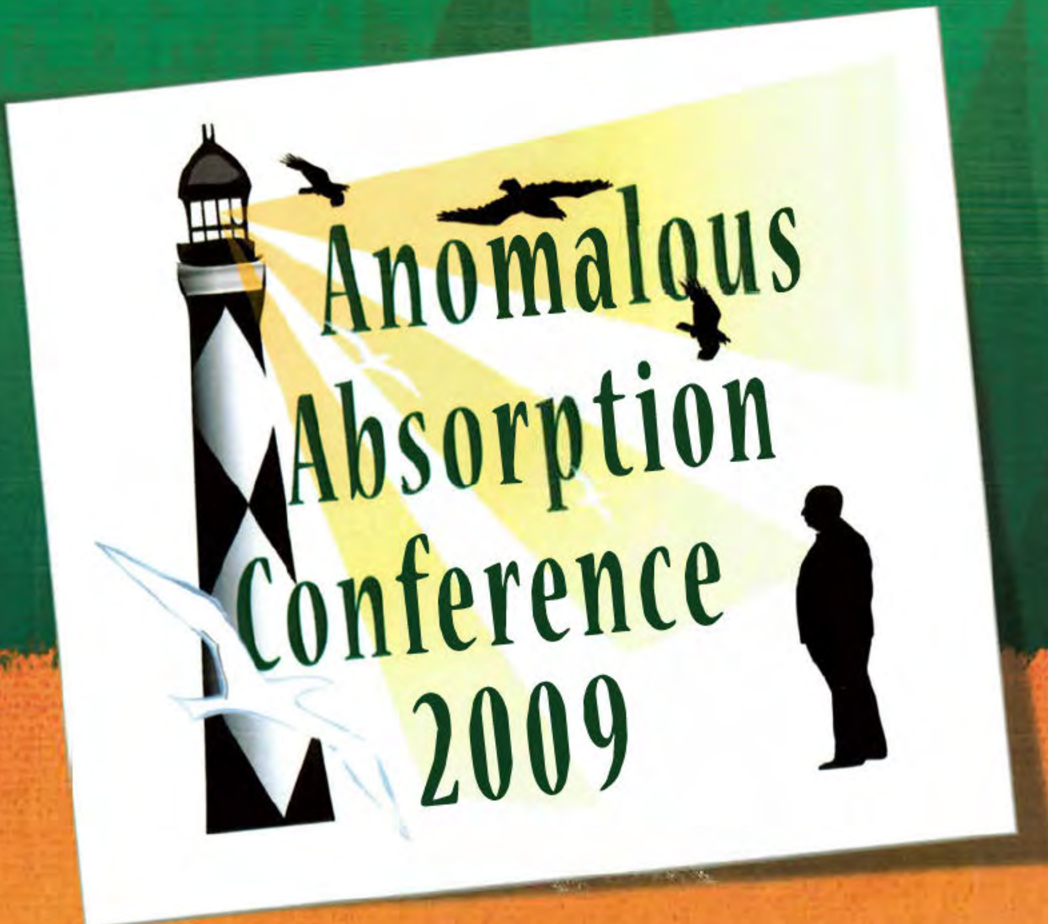

June 14-19, 2009

Bodega Bay, CA

Abstract Book

39th Annual

Anomalous Absorption Conference

Bodega Bay, California

June 14-19, 2009

Welcome to...

The 39th Annual Anomalous Absorption Conference!

Bodega Bay Lodge

Organizing/Program Committee

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Name: [redacted] Affiliation: [redacted]

39th Annual Anomalous Absorption Conference
June 14-19, 2009
Bodega Bay, CA
Agenda

Sunday - June 14, 2009 - Reception			
SUNDAY	**6:00-8:00 P.M.**	**Check-In Reception**	**Waveside Room**
Monday - June 15, 2009 - LPI I			
MONDAY	**8:45 AM - 12:20 PM**	**ORAL SESSION 1**	**Waveside Room CHAIR - D. E. HINKEL**
	8:45 AM	D. E. Hinkel	Welcome / Introduction
Guest Speaker	**9:00 AM**	**S. Depierreux**	Laser Plasma Interaction in Foam Plasmas on the LIL Facility
M01	9:30 AM	P. Loiseau	Laser-Plasma Interaction Experiments in Gas-Filled Hohlraums at the LIL Facility
M02	9:50 AM	C. Riconda	Gas Jet Studies of Stimulated Brillouin Scattering in the Strong Coupling Regime
M03	10:10 AM	B. J. Winjum	The Effects of Convecting Plasma Wave Packets in Stimulated Raman Scattering
M04	10:30 AM	D. H. Edgell	Time-Dependent Scattered-Laser-Light Spectroscopy and Cross-Beam EnergyTransport in Direct-Drive-Implosion Experiments
BREAK	10:50 AM	BREAK	
M05	11:20 AM	R. W. Short	Anisotropy of Two-Plasmon Decay for Multiple Obliquely Incident Laser Beams
M06	11:40 AM	A. V. Maximov	Modeling of Two- Plasmon- Decay Instability Under Crossed- Beams Irradiation
M07	12:00 PM	R. Yan	The Growth and Saturation of the Two-Plasmon DecayInstability in Inertial Confinement Fusion
INVITED TALK	**7:30 - 8:30 PM**		**Waveside Room CHAIR - R. E. OLSON**
		D. Callahan	Optimizing the NIF Ignition Point Design Hohlraum
MONDAY	**8:30 - 10:00 PM**	**POSTER SESSION 1**	**Dolphin Room**
MP1		B. Albright	Three Dimensional Particle-In-Cell Simulations of Stimulated Raman Scattering and a Simple Model for the Effects of "Above-Threshold" Speckles
MP2		R. Berger	How Predictive is F3D and are OMEGA Experiments Relevant to NIF?
MP3		F. Fiuza	On the Possibility of Fast Ignition Assisted by Relativistic Shocks
MP4		T. Grismayer	A PIC Simulation Study on the Evolution of the Real and Imaginary Frequencies of 1D Plasma Waves
MP5		D. D.-M. Ho	NIF Ignition Target with High-Density Carbon (HDC) Ablator

MP6		C. M. Huntington	Development of Radiative Shock Experiments on the Omega Laser
MP7		A. B. Langdon	Time-Dependent Stimulated Scatter in NIF Ignition Targets
MP8		S. H. Langer	Simulating National Ignition Campaign X-ray Detectors
MP9		C. Rousseux	Preliminary LPI Experiments of the Interaction of a 3ω, 15 kJ, 6-ns Laser Pulse in Gas-Filled Hohlraums at the LIL Facility
MP10		C. H. Still	Multifrequency SRS Modeling with pF3d
MP11		C. Thomas	The Interpretation of Hard X-ray Measurements at the National Ignition Facility (NIF)
MP12		F. S. Tsung	Nonlinear Behavior of the Two Plasmon and High Frequency Hybrid
MP13		D. Russell	3/2 w_0 Emission from the LDI Langmuir Waves Excited in the Nonlinear Saturation of the Two Plasmon Decay Instability

Tuesday - June 16, 2009 Rad-Hydro / LPI II

TUESDAY	**8:45 AM - 12:20 PM**	**ORAL SESSION 2**	**Waveside Room CHAIR - D. CALLAHAN**
Guest Speaker	**9:00 AM**	**N. B. Meezan**	3D Radiation Hydrodynamics Simulations of NIF Hohlraum Energetics Experiments
T01	9:30 AM	J. L. Kline	Vacuum Hohlraum Energetic Experiments on the National Ignition Facility
T02	9:50 AM	R. E. Olson	X-ray Conversion Efficiency in Low-Z and Mid-Z Lined Hohlraum Targets
T03	10:10 AM	E. Williams	Modeling Stimulated Brillouin Scattering in NIF Vacuum Hohlraum Experiments
T04	10:30 AM	D. D.-M. Ho	LIFE Hohlraum with One-Sided Illumination and the Limit on Illumination Asymmetries for Fast-Ignitor Capsules
BREAK	**10:50 AM**	**BREAK**	
T05	11:20 AM	M. J. Schmitt	Calculations of the Implosion Velocities of Copper-Doped Beryllium Capsules Shot on the Omega Laser
T06	11:40 AM	C. K. Li	Pressure-Driven, Resistive Interchange Instabilities in Laser-Produced, High-Energy-Density Plasmas
T07	12:00 PM	P. Amendt	Design of an Indirect-Drive Non-Cryogenic Double-Shell Target Driven by a 1ω Nd Laser
INVITED TALK	**7:30 - 8:30 PM**		**Waveside Room CHAIR - A. B. LANGDON**
		W. P. Leemans	Progress on Laser-Plasma Acceleration Using Spatially Tailored Plasmas
OPEN FORUM	**8:30-9:30 PM**	**DISCUSSION Section**	**Waveside Room CHAIR - D. E. HINKEL**

Wednesday - June 17, 2009 - Accelerator / Short-Pulse Physics

WEDNESDAY	**9:00 AM - 1:00 PM**	**ORAL SESSION 3**	**Waveside Room CHAIR - W. KRUER**
W01	9:00 AM	C. G. R. Geddes	Multi-GeV Laser Wakefield Accelerator Stage and Controlled Injection Simulations
W02	9:20 AM	E. Esarey	Laser Plasma Acceleration with Higher-Order Modes
W03	9:40 AM	A. Pak	Investigation of Ionization Induced Trapping in a Laser Wakefield Accelerator

W04	10:00 AM	J. E. Ralph	700 MeV Electrons from an 8.5 mm Self-Guided Laser Wakefield Accelerator
Guest Speaker	**10:20 AM**	**W. B. Mori**	Laser Wakefield Acceleration: Recent Developments in Theory and Simulation
W05	10:50 AM	C. B. Schroeder	Intense, Short-Pulse Laser Evolution and Depletion in Underdense Plasma
BREAK	**11:10 AM**	**BREAK**	
W06	11:40 AM	J. May	On Electron Acceleration by High Intensity Lasers in Steep Density Gradients
W07	12:00 PM	S. J. Hughes	Hot Electron Transport Modelling with Non-Spitzer Resistivity Using THOR
W08	12:20 PM	C. Ren	PIC Simulations of Laser Channeling in Millimeter- Scale Underdense Plasmas for Fast Ignition
W09	12:40 PM	J. Tonge	On the Advantages of Fast Ignition with Ultra High Intensity Lasers
INVITED TALK	**7:30 - 8:30 PM**		**Waveside Room** **CHAIR - H. A. BALDIS**
		S. Glenzer	The Hohlraum Energetics Experimental Campaign on the National Ignit
WEDNESDAY	**8:30 - 10:00 PM**	**POSTER SESSION 2**	**Dolphin Room**
WP1		P. Amendt	Simulations of Plasma Fows in Vacuum Hohlraums: Can we Explain a Commonly Observed Jet-Like Phenomenon?
WP2		J. Banks / J. Hittinger	VALHALLA: An Adaptive, Continuum Vlasov Code for Laser Plasma Interaction
WP3		S. Depierreux	Laser Plasma Interaction Experiments on LULI 2000
WP4		C. Di Stefano	Spike Morphology in Blast-Wave-Driven Instability Experiments Relevant to Supernovae
WP5		E. S. Dodd	Simulations of Direct-Drive Capsule Experiments at OMEGA
WP6		J. E. Fahlen	Finite-Size Effects in Electron Plasma Waves and their Application to SRS
WP7		S. M. Finnegan	Effects of Binary Particle Collisions on the Onset of Backward Stimulated Raman Scattering of Laser in Kinetic Regime
WP8		W. L. Kruer	Reducing Laser Plasma Interaction Surprises in Ignition-Scale Hohlraums
WP9		P.-E. Masson-Laborde	Kinetic Simulations of Stimulated Raman Scattering
WP10		M. V. Patel	Assessing the Sensitivity of ICF Hohlraum Conditions to NLTE Opacity Modeling
WP11		D. Pesme	Instabilities of an Ion Acoustic Wave in the Presence of a Ion Kinetic Effects
WP12		M. D. Rosen	The Curiously Small Spot Size (in 3 keV x-rays) From a Larger Spot Laser Irradiance
WP13		D. J. Strozzi	Electron Transport Simulations for Fast Ignition on NIF FI

Thursday - June 18, 2009 - LPI III

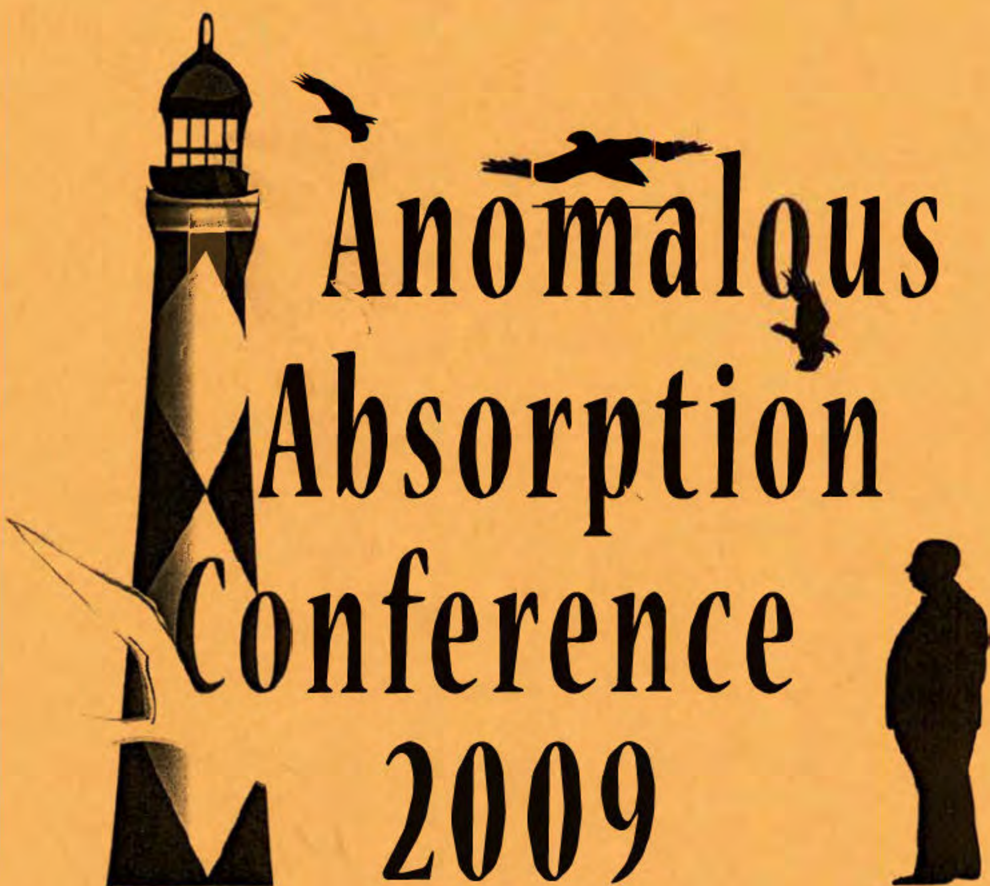
THURSDAY	**9:00 AM - 11:10 AM**	**ORAL SESSION 4**	**Waveside Room CHAIR - D. J. STROZZI**
Guest Speaker	**9:00 AM**	**W. Seka**	Experiments Indicate that the Two-Plasmon-Decay Instability is Insensitive to Laser Speckle
TH01	9:30 AM	J. F. Myatt	Extended Zakharov Predictions of Anomalous Absorption in Inhomogeneous ICF Relevant Plasma Due to the Two Plasmon Decay
TH02	9:50 AM	D. Dubois	1/2 ω_0 Emission from the Nonlinear Currents Generated by the Two Plasmon Decay Instability
TH03	10:10 AM	H. Vu	Hot Electron Production from the Two Plasmon Decay Instability
TH04	10:30 AM	J. P. Palastro	Kinetic Dispersion of Langmuir Waves
TH05	10:50 AM	R. Kirkwood	Amplification of Light by Langmuir Waves in a Hot, Strongly Damped Plasma and its Relevance to Ignition and Pulse Compression
BUSINESS MEETING	**11:10 AM**		**Waveside Room**
ACTIVITIES	**2-5:30 PM**		**Doran Beach**
REFRESHMENTS	**5:30 - 6:30 PM**		
BANQUET	**6:30 PM**		

Friday - June 19, 2009 - LPI IV

FRIDAY	**8:45 AM - 12:00 PM**	**ORAL SESSION 5**	**Waveside Room CHAIR - A. B. LANGDON**
F01	9:00 AM	D. E. Hinkel	Laser-Plasma Interactions in Emulators of NIF Ignition Targets
Guest Speaker	**9:20 AM**	**P. Michel**	Collective Amplification of Stimulated Raman and Brillouin Scattering by Multiple Laser Beams in Ignition Experiments
F02	9:50 AM	R. L. Berger	What do OMEGA Experiments ResultS Say About the Suppression of Stimulated Brillouin Scattering from NIF Hohlraums With Gold-Boron Layers?
F03	10:10 AM	L. Divol	Speckles Effect in Stimulated Backscatter
F04	10:30 AM	D. J. Strozzi	Role of Electron Trapping in SRS on NIF Ignition Targets
BREAK	**10:50 AM**	**BREAK**	
F05	11:20 AM	L. Yin	Saturation of Backward Stimulated Raman Scattering of Laser in Trapping Regime
F06	11:40 AM	P.-E. Masson-Laborde	Self-Focusing Induced Reduction of Stimulated Brillouin Scattering of Intense Laser Beams Interacting with Expanding Plasmas
	12:00 P.M.	**Adjourn**	

ORAL SESSION 1

LPI I



Anomalous Absorption Conference 2009

June 15, 2009

Monday

Chair – D. E. Hinkel

S. Depierreux ✦ P. Loiseau ✦ C. Riconda ✦ B. J. Winjum ✦ D. H. Edgell ✦ R. W. Short ✦ A. V. Maximov ✦ R. Yan

39th Annual Anomalous Absorption Conference
Bodega Bay, CA
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Laser plasma interaction in foam plasmas on the LIL facility*

S. Depierreux[1], C. Labaune[2], V. T. Tikhonchuk[3], D. T. Michel[1,2], C. Stenz[3], N. G. Borisenko[4], P. Nicolaï[3], M. Grech[3,5], G. Riazuelo[1], S. Hüller[6], D. Pesme[6], P. Loiseau[1], P.E. Masson-Laborde[1], M. Casanova[1], C. Riconda[2], S. Weber[3], S. Darbon[1], R. Wrobel[1], E. Alozy[1], W. Nazarov[7], J. Limpouch[8], A. Casner[9], C. Meyer[9], P. Romary[9], G. Thiell[9]

[1]*CEA, DAM, DIF, F-91297 Arpajon, France*
[2]*Laboratoire pour l'Utilisation des Lasers Intenses, Ecole Polytechnique, Palaiseau, France*
[3]*Centre Lasers Intenses et Applications, Université Bordeaux 1, CEA, CNRS, Talence, France*
[4]*P. N. Lebedev Physical Institute, Russian Academy of Sciences, Moscow, Russia*
[5]*Max Planck Institute for the Physics of Complex Systems, 01187 Dresden, Germany*
[6]*Centre de Physique Théorique, Ecole Polytechnique, 91128 Palaiseau cedex, France*
[7]*University of St. Andrews, Fife KY16 9ST, Scotland, UK*
[8]*FNSPE, Czech Technical University in Prague, 115 19 Prague 1, Czech Republic*
[9]*CEA, CESTA, F- 33114 Le Barp, France*

A new target design for avoiding the imprint problem in the direct drive scheme has been proposed and tested on the LIL facility. It uses a low density foam layer inserted in front of the target. The foam is directly ionized by the laser. Then, the laser beam, propagating in the resulting underdense preformed plasma is smoothed by plasma smoothing mechanisms. Two series of experiments have been conducted on the LIL facility for evaluating this scheme. For these experiments, the LIL facility delivered a 4 TW square pulse (typically 10 kJ in 3 ns).

The first experiment, conducted in June 07, demonstrated the effectiveness of a 500 μm layer of 10 mg/cc foam for smoothing the 3ω laser beams in the initial interaction phase. Self X ray emission observed in the transverse direction provided measurement of the propagation of the ionization front. A supersonic ionization wave sustained for the whole ionisation process (~1.2 ns) was observed. Demonstration of the foam plasma smoothing effect was observed (i) directly by analyzing the angular spreading of the transmitted light and (ii) indirectly through the observation of X ray emission of a high Z thick foil placed behind the foam.

The second experiment, performed this year, was devoted to a parametric study of laser plasma interaction in foam plasmas. The main diagnostics were SRS and SBS scattering as well as tranmission of the laser beams. The foam (density, length and dopant) and laser (energy, smoothing) parameters were varied. A new measurement in addition to the standard transmitted beam diagnostic was set up for this experiment. It provides time and spectrally resolved measurement of the light scattered at 10° and 20° of the directly transmitted beam.

The experimental set up and the main results will be presented and discussed.

* This work was coordinated under the auspice of the Institut Lasers and Plasmas.

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Laser-Plasma Interaction Experiments In Gas-Filled Hohlraums At The LIL Facility

P. Loiseau, M. Casanova, C. Rousseaux, D. Teychenn´e, P-E. Masson-Laborde, S. Laffite and G. Huser

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The first laser-plasma interaction (LPI) campaign conducted at the LIL facility, using gas-filled hohlraums, ended in spring 09. The LIL facility is a prototype of one quadruplet of the near coming french laser megajoule (LMJ). Two differents gas-filled hohlraums have been designed in order to mimic plasma conditions that are expected along two particular beam paths in ignition hohlraums. The targets consist of 3- or 4-millimeters long, 1 atm neo-pentane gas-filled gold hohlraums. One target is closed at the opposite side of the laser entrance hole, allowing laser interaction with gold and gas plasmas. The LIL quadruplet is aligned with the hohlraum's axis and deliver a 6-ns long pulse with 15 kJ at 3!. Optical smoothing is achieved by longitudinal dispersion and a phase plate giving a near 10^{15} W/cm^2 mean intensity on the focal spot at maximum power. Many LPI diagnostics were activated during the campaign, allowing a full temporal and angular description of parametric instabilities such as stimulated Brillouin (SBS) or Raman (SRS) scattering.

We will present and discuss hydrodynamic calculations together with preliminary results of the LPI campaign. Hydrodynamic calculations predict a 3 keV on-axis electron temperature and an electron density evolving on a wide range of densities during the pulse. Calculated plasma conditions allow to evaluate SBS and SRS linear gains. The corresponding spectra are compared to experimental results and confirm the complex plasma evolution. Finally, We use the 3D paraxial code HERA[1] to investigate the propagation of the LIL quad, by means of massivelly parallel simulations.

1 Loiseau *et al*., Phys. Rev. Lett. 97, 205001 (2006); Ballereau *et al*., J. Scient. Comput. 33, 1 (2007).

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Gas Jet Studies of Stimulated Brillouin Scattering in the Strong Coupling Regime

C. Riconda, L. Lancia, J-R. Marquès, J. Fuchs *,
S. Weber, V.T. Tikhonchuk**, A. Héron, S. Hüller***

**LULI, Université Paris 6, CNRS, CEA, École Polytechnique,France*
***CELIA, Université Bordeaux1, CNRS, CEA, France*
***CPHT, CNRS, *École Polytechnique, France*

Recent experimental results[1] of laser propagating in large scale (<~mm), well characterized homogeneous plasmas created using gas jets, have motivated theoretical and numerical analysis of laser plasma interaction in a domain not yet fully explored. The plasma characteristics are such that Stimulated Brillouin Scattering is in the strong coupling regime, leading to a rapid (sub-ps) evolution of the plasma ions, by the interaction with the laser. In particular the coherence and transmission properties of a 7 ps pulse at $I\lambda^2 >= 10^{16}$ are presented. A transition in the laser behavior is observed as the density increases from few percent to 0.15-0.3 critical density.

The coupling of this pulse (labeled "the pump"), and a second counter-propagating pulse (labeled "the seed") of smaller intensity results in energy transfer from the pump to the seed, with due amplification of the seed. The efficiency of this mechanism is also explored as function of plasma density.

[1] L. Lancia, J-R. Marquès, J. Fuchs, M. Nakatsutsumi, A. Mancic, P. Antici, C. Riconda, S. Weber, V.T. Tikhonchuk, A. Héron, S. Hüller, J-C. Adam, and P. Audebert "Experimental investigation of identical wavelength short light pulses crossing in underdense plasma'', Proceedings of SPIE Euro Opto and Optoelectronics Conference, Prague, Czech Republic, April 2009.

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The effects of convecting plasma wave packets in stimulated Raman scattering *

B. J. Winjum, J. E. Fahlen, F. S. Tsung, W. B. Mori
UCLA

Stimulated Raman scattering (SRS) for NIF-relevant parameters involves nonlinear, kinetic physics. Previous simulations have focused on the nonlinear physics involved in SRS saturation (such as nonlinear frequency shifts and trapped-particle sideband instabilities) in isolation from and without regard to finite spatial effects. However, SRS is bursty in both space and time, generating plasma wave packets that can interact with each other through the scattered light. Simulations that are too small artificially prevent this interaction, forcing the recurrence to be more periodic than it would otherwise be and limiting the reflectivity. The larger simulations presented here allow several packets to grow and convect simultaneously. In this case, SRS reflectivity is larger because the packets interact as the backscattered light from one packet provides an enhanced seed for a nearby packet. Nonlinear frequency shifts in the packets are also shown to generate higher frequency bursts of scattered light, further increasing the reflectivity. We present results for both 1D and 2D simulations.

*This work was supported by DOE under Grant Nos. DE-FG52-03-NA00065, DE-FG52-06NA26195, and DE-FG02-03ER54721, and simulations were carried out on the DAWSON Cluster supported under NSF grant No. NSF-Phy-0321345.

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Time-Dependent Scattered-Laser-Light Spectroscopy and Cross-Beam Energy Transport in Direct-Drive-Implosion Experiments

D. H. Edgell, W. Seka, J. A. Delettrez, R. S. Craxton, V. N. Goncharov, I. V. Igumenshchev, J. F. Myatt, A. V. Maximov, R. W. Short, T. C. Sangster, and R. E. Bahr

Laboratory for Laser Energetics, University of Rochester
250 East River Road, Rochester, NY 14623-1299

Time-resolved scattered-light spectroscopy near λ = 351 nm from spherical target implosions on OMEGA provides information about time-dependent laser–plasma interactions. The time-dependent absorbed fraction during spherical room-temperature and cryogenic direct-drive implosions is inferred from integrating these spectra over all measured wavelengths. The time-dependent spectral shift of the scattered light results from a combination of a Doppler shift caused by the evolving coronal plasma and nonlinear processes that can shift energy between crossed beams. A ray-trace code models the Doppler spectral shifts of the measured scattered light using plasma profiles calculated by a hydrodynamic code that incorporates the Goncharov nonlocal electronheat- transport model.[1] The modeled spectra reproduce the major features in the observed spectral shifts, but the absolute magnitudes of the predicted spectral shifts and the total scattered light do not match experimental measurements during the latter part of the laser pulse where more scattered light and smaller spectral shifts are observed. While the overall absorption discrepancy is small (typically a difference of only 10% to 15% of the total time-integrated laser-pulse power), additional physics is needed for the modeling to match the observations. Nonlinear energy exchange between crossed beams due to electromagnetic-seeded stimulated Brillouin scattering is suggested as a possible explanation. Preliminary calculations of cross-beam energy transfer indicate that the effect may be of the correct order to explain the discrepancies.

*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.

1. V. N. Goncharov *et al.*, Phys. Plasmas **13**, 012702 (2006).

Anisotropy of Two-Plasmon Decay for Multiple Obliquely Incident Laser Beams

R. W. Short

Laboratory for Laser Energetics, University of Rochester
250 East River Road, Rochester, NY 14623-1299

Experimental observations of 3/2 harmonic and hard x-ray emission on OMEGA have shown that two plasmon decay (TPD) signals depend on the collective rather than the single-beam intensity.[1] Previous theoretical work has shown that if one of the plasmon wavevectors is aligned along the density gradient and the axis of symmetry of several laser beams, the beams act in concert and result in the same growth as would be obtained for a single beam at the combined intensity.[2] In this talk this analysis will be extended to plasmon wavevectors that deviate from the axis of symmetry or from the density gradient. The dependence of the integrated growth of the instability on the angle of deviation will be determined. In a direct-drive spherical configuration this dependence determines the anisotropy of the resulting hot electron distribution, and so is important in modeling the preheat of the core by TPD-generated hot electrons.[3]

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.

1. C. Stoeckl *et al.*, Phys. Rev. Lett. **90**, 235002 (2003).
2. R. W. Short, Bull Am. Phys. Soc. **53**, 245 (2008).
3. J. A. Delettrez *et al.*, Bull Am. Phys. Soc. **53**, 248 (2008).

Prefer oral presentation.

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Modeling of Two-Plasmon-Decay Instability Under Crossed-Beams Irradiation

A. V. Maximov, J. F. Myatt, R. W. Short, W. Seka, J. A. Delettrez, C. Stoeckl
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The two-plasmon decay (TPD) instability has a threshold low enough to be exceeded for the typical parameters of the inertial confinement fusion experiments in the direct-drive regime.[1,2] Therefore, the TPD and the resulting generation of hot electrons are important features of laser–plasma interaction in the experiments on the Omega Laser System[1,2] and in future experiments at the National Ignition Facility (NIF). The characteristic feature of these experiments is that the laser–plasma interaction is driven by multiple crossing laser beams, which are randomized in space due to distributed phase plates and randomized in time due to smoothing by spectral dispersion.

To study the instability under the crossed-beams irradiation, a model has been developed for the TPD driven by randomized laser beams in inhomogeneous plasmas. The instability thresholds can differ from the results of the three-wave TPD model in inhomogeneous plasmas.[3]

The saturation of the TPD instability is found to be caused by low-frequency ion-acoustic perturbations in plasma. These perturbations include the waves driven by the laser beams and the waves driven by the ponderomotive force of plasma waves, including the Langmuir decay instability. The properties of the ion-acoustic waves, namely the ion-acoustic damping, influence the saturation of the TPD, making the TPD sensitive to the ion composition of plasmas.

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.

1. C. Stoeckl *et al.*, Phys. Rev. Lett. **90**, 235002 (2003).
2. W. Seka *et al.*, "Two-Plasmon-Decay Instability in Direct-Drive Inertial Confinement Fusion Experiments," to be published in Phys. Plasmas **16** (2009).
3. A. Simon, R. W. Short, E. A. Williams, and T. Dewandre, Phys. Fluids **26**, 3107 (1983).

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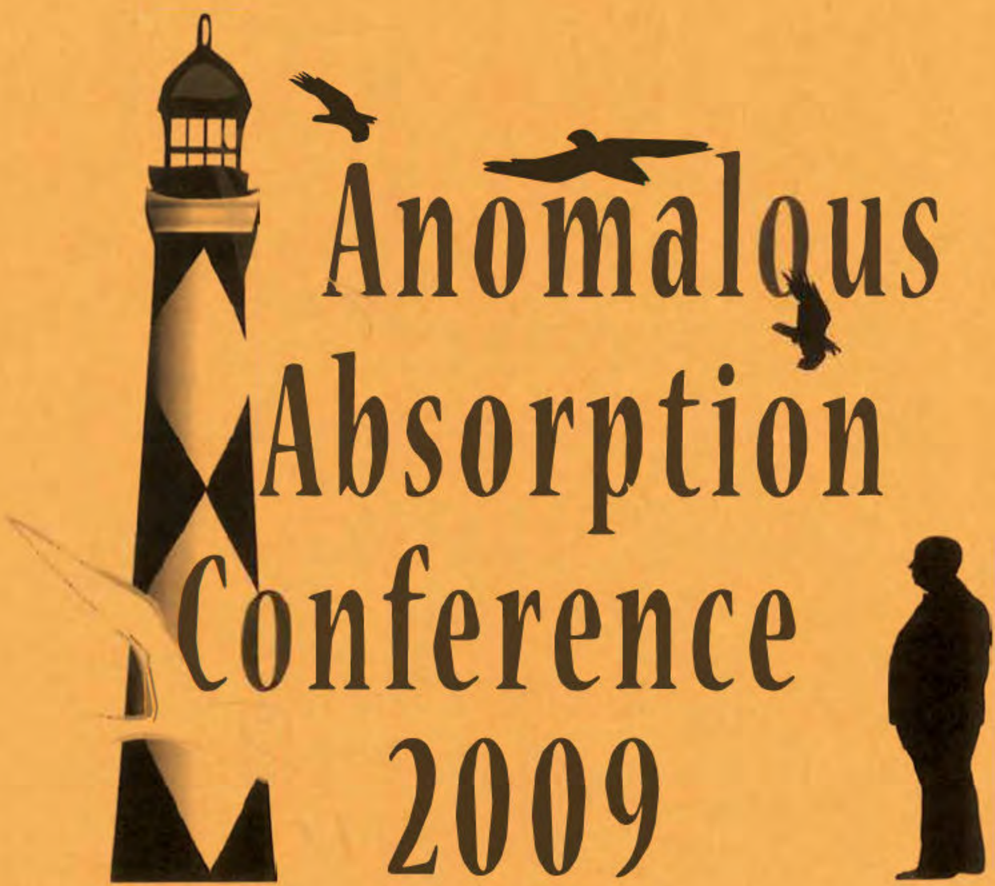
The growth and saturation of the two-plasmon decay instability in inertial confinement fusion

Rui Yan, Andrei Maximov, Chuang Ren
University of Rochester, Rochester, NY 14627
Frank Tsung
University of California, Los Angeles, CA 90095

We present particle-in-cell (PIC) and fluid simulations on the two-plasmon-decay (TPD) instability under conditions relevant to direct-drive inertial confinement fusion experiments. Under these conditions, the PIC simulations show a wide TPD spectrum, with modes whose perpendicular mode number $k_\perp$ larger than the cutoff predicted by the linear theory for absolute modes. The fluid simulations, solving the full set of the linear equations of TPD, clearly show that these large- $k_\perp$ modes are convective and have linear growth rates comparable to the absolute modes. The convective modes grow at the lower density region and can cause pump depletion, reducing the growth of the absolute modes. Even though they saturate before reaching the convective limit, the convective modes are energetically dominant in the nonlinear stage. The PIC simulations show that both the absolute and convective modes saturate due to ion density fluctuations, which can turn off TPD by raising the instability threshold through mode coupling and lead to intermittent growth. The results show that the convective modes of TPD are important to the performance of current and future direct-drive experiments. This work was supported by U.S. Department of Energy under Grants Nos. DE-FG02-06ER54879 and DE-FC02-04ER54789. The research used resources of the National Energy Research Scientific Computing Center.

Invited Talk 1

Optimizing the NIF Ignition Point Design Hohlraum



June 15, 2009

Monday
Chair – R. E. Olson

✦ D. Callahan ✦

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Optimizing the NIF Ignition Point Design Hohlraum *

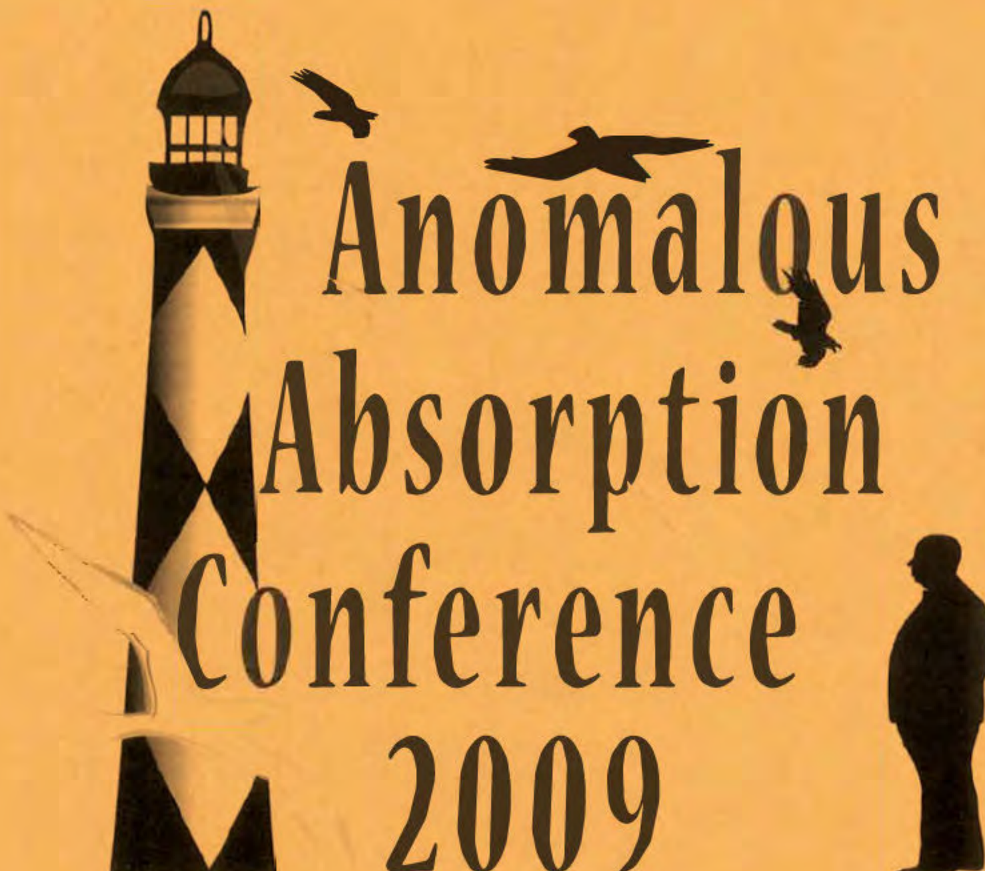
D. Callahan, R. Town, D. Hinkel, L. Divol, S. Dixit, J. Edwards, D. Froula, S. Glenzer, S. Haan, J. Lindl, P. Michel, N. Meezan, O. Jones, L. Suter, E. Williams

Lawrence Livermore National Laboratory

To optimize the NIF ignition point design hohlraum, we need to trade-off between the different requirements. Over the last several years, a multi-disciplinary team has been working to understand these requirements and to quantify the trade-offs in order to optimize the point design. These factors include target physics (such as capsule performance, energetics, symmetry and laser plasma interactions), laser requirements (such as peak power, total laser energy, and beam spot size), target fabrication (such as choice of hohlraum materials, and fabrication yield) and facility impact. We have considered designs using three ablators (Be, CH, and high-density-carbon) and radiation drive temperatures ranging from 270 eV to 300 eV. We have also considered contingency designs with larger laser-entrance-holes (LEH) that allow larger beams (with lower intensity) and contingency designs without an LEH lip liner to reduce the plasma density in the LEH region. We have also studied the robustness of the design by varying the physics models used in the calculation (heat transport and non-LTE emissivity, for example). In this talk, we will describe the choices that we have made for the ignition point design and the logic that led us to those choices.

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

POSTER SESSION 1



Anomalous Absorption Conference 2009

June 15, 2009

Monday

B. Albright ✦ R. Berger ✦ F. Fiuza ✦ T. Grismayer ✦ D. D.-M. Ho ✦ C. M. Huntington ✦ A. B. Langdon ✦ S. H. Langer
C. Rousseux ✦ C. H. Still ✦ C. Thomas ✦ F. S. Tsung ✦ D. Russell

39th Annual Anomalous Absorption Conference
Bodega Bay, CA
June 14-19, 2009

Three dimensional particle-in-cell simulations of stimulated Raman scattering and a simple model for the effects of "above-threshold" speckles*

Brian J. Albright, Lin Yin, Kevin J. Bowers†, Harvey A. Rose, Benjamin K. Bergen, Sean M. Finnegan, David S. Montgomery, John L. Kline, and Juan C. Fernández
Los Alamos National Laboratory

A suite of three-dimensional particle-in-cell simulations of solitary laser speckles has been conducted using the VPIC particle-in-cell code [1], which has been modified to run on the Roadrunner supercomputer, the first machine to achieve petaflop/s performance on the Linpack benchmark. These simulations, performed under NIF hohlraum plasma conditions, exhibit nonlinearity consistent with that reported by Montgomery et al. [2] from Trident single-speckle experiments. Namely, a sharp increase in reflectivity is found at a threshold laser intensity I_{th}, followed by a saturation at intensity $I > I_{th}$. Earlier work [3] obtained the essential nature of stimulated Raman scattering (SRS) in these regimes and the role of plasma wave-front bowing and secondary instability in SRS saturation. Extension of this work to three dimensions [4] shows that for the same laser f/#, there is a general trend toward higher onset threshold I_{th} and lower saturated reflectivity in three dimensions than in two dimensions. These simulation results may be used in a simple model to predict the contribution of a small population of "above- threshold" speckles to overall SRS reflectivity.

[1] Bowers, Kevin J., B. J. Albright, L. Yin, and T. J. T. Kwan, Phys. Plasmas 15, 055703 (2008).
[2] Montgomery, D. S. et al. Phys. Plasmas 9, 2311 (2002).
[3] Yin, L., B. J. Albright, K. J. Bowers, and H. A. Rose, Phys. Rev. Lett. 99, 265004 (2007).
[4] Yin L. et al., Phys. Plasmas (submitted).

*Work performed under the auspices of the U.S. Dept. of Energy by the Los Alamos National Security LLC, Los Alamos National Laboratory.

†LANL Guest Scientist; presently at D. E. Shaw Research LLC, 120 W 45th Street, 39th Floor, New York, NY 10036.

39th Annual Anomalous Absorption Conference
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How predictive is F3D and are OMEGA experiments relevant to NIF?

R. L. Berger, L. Divol, D. Froula, S. H Glenzer, R. London, N. Meezan, P. Michel, P. Neumayer, L. J. Suter, D. E. Hinkel, A. B Langdon, C.H. Still, D. J. Strozzi, E.A. Williams, and H. A. Rose
Lawrence Livermore National Laboratory
Livermore, CA 94551

Recently, a number of experiments at the OMEGA laser facility have tested the capabilities of pF3D to predict the propagation of laser light through millimeter scale hot underdense plasma. The SRS and SBS reflectivity and the fraction of transmitted light have predicted the measured values with surprising success given the fact that some well known kinetic and fluid nonlinear effects have been omitted from the simulations. The success extends to the spectra of the transmitted and reflected light and to the distribution of light across the collection optics. The effect of polarization smoothing (PS) and smoothing-by-spectral-dispersion (SSD) on SRS and SBS was also predicted successfully, even predicting no effect in some cases. Recently the f-number scaling of the SRS reflectivity was measured to agree with pre-shot predictions. The key enabling factors for this predictive capability were an extensive rad-hydrodynamics design validated by Thomson scattering, use of the actual measured boundary conditions for the laser (phase plates, smoothing techniques) and access to routine teraflop computing power to allow full three dimensional simulations.

We will examine if the plasma parameters for the OMEGA experiments are in a parameter range where nonlinear effects are minimal and to what extent that is also true for the predicted NIF plasma parameters. Simple nonlinear models of some kinetic nonlinearities will be applied to the results.

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

39th Annual Anomalous Absorption Conference
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On the possibility of fast ignition assisted by relativistic shocks

F. Fiuza, R. A. Fonseca, L. O. Silva
GoLP/IPFN, Instituto Superior Técnico, Lisbon, Portugal

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W. B. Mori
Department of Electrical Engineering, University of California, Los Angeles and Department of Physics & Astronomy, University of California, Los Angeles, CA 90095

C. Ren
University of Rochester

One of the critical issues for fast ignition of fusion targets is to understand and optimize the coupling of the ignition laser to the fast particles, and the transport of the accelerated particles in the mildly dense region of the target.

We have performed a series of one-dimensional (1D) and two-dimensional (2D) PIC simulations in order to examine laser absorption into hot electrons, electron transport and energy absorption into the core of the target using ignition lasers with ultrahigh intensities, up to $5x10^{21}$ W/cm^2. We have simulated target densities from the critical density, nc, to 1000 nc, and we have used an absorbing core in order to avoid the unphysical reflux of the inward electrons through the target. This core represents the higher density region as an energy dependent drag on hot electrons, allowing for measurements of the total energy deposited in the high density region of the fast ignition target.

Our results show that at these ultrahigh intensities a shock is launched, mediated by ion driven instabilities in 1D and by the Weibel driven magnetic fields in 2D. The 1D and 2D dynamics of the shock is compared. A significant amount of energy is bottled behind the shock front. The detailed study of the evolution of the shock and heat-front along the density gradient shows the possibility of releasing the bottled energy into the core of the target, allowing, in principle, for higher efficiencies.

*The authors gratefully acknowledge the support of the HiPER project in undertaking this work (EC FP7 project number 211737), and support by NSF under Grant No. PHY-0078508, and by DOE under Contract Nos. DE-FG03-NA0065 and DE-FG02-03ER54721 and DE-FG02-06ER54879.

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Bodega Bay, CA
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A PIC simulation study on the evolution of the real and imaginary frequencies of 1D plasma waves*

T. Grismayer, J. Fahlen, B. Winjum, F. Tsung, G. Morales and W.B. Mori
UCLA

We use electrostatic PIC simulations to study the evolution of both the real and complex frequency of 1D plasma waves. We considered two regimes. In the first regime, $\gamma/\omega_b >> 1$, where γ and ω_b are the asymptotic damping rate and bounce frequency respectively. In this regime the waves are typically very small and below the thermal noise. These waves can be studied using a subtraction technique where two simulations where identical random number generation seeds are carried out. In the first, a small amplitude wave is excited. In the second reference simulation no wave is excited. The results from each simulation are subtracted providing a clean linear wave that can be studied. As previously predicted, the damping is divided in two stages, an initial transient and an asymptotic decay (Landau's formula). The time-dependent resonant width measured in the simulations is compared with the theoretical prediction. In typical ICF plasmas $nl_d^3 <\sim 10^3$. Therefore, the number of resonant electrons can be small for linear waves. We will consider the effects of small numbers of resonant particles and their consequences of the observed damping.

The evolution of the real and imaginary frequencies is also considered for non linear plasma waves (i.e, for $\gamma/\omega_b << 1$). Specifically we consider the evolution of impulse excited plasma waves in the kinetic regime ($k\lambda_D > 0.3$). The simulation results are in reasonable agreement with the transient and asymptotic theoretical predictions of Morales and O'Neil for parameters where their theory is appropriate. Furthermore, robustness of the theory holds is tested by varying the parameters outside of the range of validity. Classical nonlinear effects such as sideband instabilities, damping rate of high amplitude plasma waves and BGK modes will also be discussed.

*This work was supported by DOE under grant Nos. DE-FG52-03-NA00065, DE-FG52-06NA26195, DE-FG02-03ER54721 and the grant from the LLNL.

39th Annual Anomalous Absorption Conference
Bodega Bay, CA
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NIF ignition target with high-density carbon (HDC) ablator*

D. D.-M. Ho, S. W. Haan, J. D. Salmonson, G. B. Zimmerman, J. A. Harte, L. Benedict, and M. R. Hermann[1]
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[1]*Sandia National Laboratory*

High-density carbon as an NIF ignition capsule ablator material has several advantages including a very smooth surface finish and small grain structure. Recent Omega experiments** show that if the first shock in the ablator is higher than about 6.5 Mbar, which is in the liquid/solid 2-phase region of the carbon phase diagram, then the shock uniformity becomes comparable to that of the Be ablator. Consequently, this is the strength that we adopt for the first shock in our latest HDC capsule design. Using various scanning techniques, the capsule configuration and drive temperature profile are optimized. We describe the 1-D margin and 2-D stability behavior of the optimized point design.

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

**P. M. Celliers private communication

39th Annual Anomalous Absorption Conference
Bodega Bay, CA
June 14-19, 2009

Development of Radiative Shock Experiments on the Omega Laser

CM Huntington[1], CC Kuranz[1], A Visco[1], MJ Grosskopf[1], SH Glenzer[2], RP Drake[1]

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2 Lawrence Livermore National Laboratory, L-399, P.O. Box 808, Livermore, California 94551, USA

Driving a shock in argon gas with velocity in excess of 100 km/s creates a system where the density and temperature structure of the shock are altered by radiation transport from the shock-heated matter. Recent experiments at the Omega Laser employed several diagnostic configurations to characterize this system, including incoherent Thomson scattering spectrometry, x-ray radiography, and a novel method of imaging the x-rays scattered from material in the high-density cooling layer. The resolution of radiographic images produced from area backlighting with chlorine He_{α} and Ly_{α} lines is measured and initial imaging Thomson scattering results are shown. Plans for future iterations of radiative shock experiments are also discussed.

* This research was sponsored by the NNSA Stewardship Sciences Academic Alliances and the National Laser User Facility through DOE Research Grants DE-FG52-07NA28058 and DE-FG52-04NA00064, and by other grants and contracts.

39th Annual Anomalous Absorption Conference
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Time-Dependent Stimulated Scatter in NIF Ignition Targets*

A. B. Langdon, D. E. Hinkel,
C. H. Still, and E. A. Williams

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Laser-plasma interactions in NIF ignition campaign targets are modeled using our massively parallel code pF3D. Our LPI modeling has advanced to be based on snapshots of the radiation-hydrodynamic plasma density, temperatures, flow, ionization state and material inside the target along with laser phase and amplitude data from the laser developers. The pF3d code models LPI for 100+ ps starting from plasma conditions acquired from radiation-hydrodynamics simulations near peak power and are thereafter based on pF3d's own calculation of hydro evolution. We wish to validate the correspondence of LPI-relevant plasma profiles in pF3d and the radiation-hydro codes. To this end, we present a comparison of pF3d streak spectra to gain streak spectra from time dependent radiation-hydrodynamic simulations.

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*This work was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under contract No. DE-AC52-07NA27344.

39th Annual Anomalous Absorption Conference
Bodega Bay, CA
June 14-19, 2009

Simulating National Ignition Campaign X-ray Detectors*

S. H. Langer[1], S. Sepke[1], G. A. Kyrala[2], O. L. Landen[1], J. Kline[2], D.H. Munro[1], M. J. Edwards[1], D. Hicks[1], J. Koch[1], R. Tommasini[1], and K. Widmann[1]

[1]*Lawrence Livermore National Laboratory*
[2]*Los Alamos National Laboratory*
LLNL-ABS-412068

The National Ignition Facility laser is complete and experiments have begun. Many National Ignition Campaign (NIC) experiments rely on x-ray detectors to diagnose conditions in the hohlraum and the capsule. We have developed methods of simulating NIC x-ray detectors that help us choose the correct detector setup before a shot and interpret the results after a shot. The simulations include important features of the detectors such as spatial, spectral, and temporal resolution and the noise levels.

This poster describes the framework used to simulate the x-ray detectors and techniques used to speed up the generation of the simulated data. Detector setup parameters from the Campaign Management Tool (the computer system that controls the NIF laser) may be loaded into the detector simulation software to ensure consistency between experiment and simulation. Examples are presented for the Dante Tr diagnostic, several multi-frame imaging detectors (GXD, HGXI, and HEXRI), a single image detector (SXI), and a streaked detector (SXD). Comparisons are made to data from shots using the NIF and Omega lasers, when available.

*This work was performed under the auspices of the Lawrence Livermore National Security, LLC, (LLNS) under Contract No. DE-AC52-07NA27344.

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Bodega Bay, CA
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Preliminary LPI experiments of the interaction of a 3ω, 15 kJ, 6-ns laser pulse in gas-filled hohlraums at the LIL facility

C. Rousseaux, G. Huser, P. Loiseau, M. Casanova, E. Alozy,
R. Wrobel, O. Henry*, G. Thiell*

CEA-DAM-DIF, Buyères-le-Châtel, 91297 Arpajon Cedex, France
**CEA-CESTA, BP 2, 33114 Le Barp, France*

The first experimental results of stimulated Raman scattering (SRS) and stimulated Brillouin scattering (SBS) measurements obtained at the Ligne d'Intégration Laser (LIL) facility (CEA-Cesta, France) will be presented. The four laser beams (quad) deliver an energy of 15 kJ at 3ω in a 6-ns, shaped pulse producing an intensity of $7x10^{14}$ W/cm^2 at maximum power. The beams are focused by means of 3ω gratings, and are optically smoothed with a random phase plate and with optionally 14 GHz laser bandwidth.

The targets consist of 1 atm, neo-pentane (C_5H_{12}) gas-filled, gold hohlraums ; 3 mm-long, hemi-spherical and 4 mm-long, opened hohlraums have been fired. The bandwidth of the laser has been varied to examine its capability to reduce LPI in such millimeter size plasmas. At the maximum of the laser power, the mean electron density and electron temperature are calculated to be 8-10% n_c and 2.5 keV respectively.

The LIL facility and the main diagnostics devoted to the experiment will be described. For SRS and SBS studies, the light backscattered into the focusing optics is spectrally and time-resolved. Near-backscattered light at 3ω, and transmitted light at 3ω are also monitored. The preliminary results will be presented and discussed conjointly with hydrodynamic calculations, presented in details by P. Loiseau.

Poster session preferred.

39th Annual Anomalous Absorption Conference
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Multifrequency SRS modeling with pF3d*

C.H. Still, D.E. Hinkel, A.B. Langdon, J.P. Palastro, and E.A. Williams
Lawrence Livermore National Laboratory
Livermore, CA 94551

Fluid electromagnetic codes like pF3d[1] simulate stimulated Raman backscatter (SRS) via coupling laser light to a Langmuir wave described by a wave equation enveloped about a specified matching frequency. This approach has been demonstrated to model SRS very well in OMEGA experiments[2]. By introducing into the model a second Langmuir wave matched to a different frequency, and extending the coupling algorithm to ensure wave action conservation, we can extend the SRS modeling to a larger range of matching conditions. Previously, this approach would have made the calculations difficult to perform, but with the advent of multi-teraflop computers, these simulations are now possible. We will discuss our modeling methodology and show preliminary results on two-frequency SRS simulations.

1. R. L. Berger, et al, *Phys. Plasmas* **5**, 4337, (1998); C. H. Still, et. al, *Phys. Plasmas* **7**, 2023 (2000).
2. L. Divol, R. L. Berger, N. B. Meezan *et al.*, *Phys. Plasmas* **15,** 056313 (2008)

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

39th Annual Anomalous Absorption Conference
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June 14-19, 2009

The interpretation of hard x-ray measurements at the National Ignition Facility (NIF)

C. Thomas, L. Suter, E. Dewald
Lawrence Livermore National Laboratory, Livermore, California 94550

The National Ignition Facility (NIF) is preparing a filter-flourescer diagnostic system (FFLEX) to measure x-ray spectra from 10 - 400 keV. Since hard radiation is a signature of laser-plasma processes (e.g. resonant absorption, SRS, etc) that produce energetic electrons (10 – 100 keV) FFLEX will be used to diagnose laser-plasma interactions (LPI) and/or suprathermal electrons. This presentation addresses the accuracy of FFLEX, and the model(s) used to relate x-ray spectra and energetic electrons. To begin, we estimate the uncertainty in measurements of 1-T and 2-T radiation profiles. We find the existing FFLEX is accurate at measuring 1-T spectra, but less accurate at measuring multi-T spectra; a finding that motivated a hardware upgrade (in progress). To complement this work, we consider the Kruer formula [1], a model used to relate x-ray spectra and hot electrons. We find considerable uncertainty is possible in the individual parameters of a fit to the Kruer formula, but surprising accuracy is possible in the Kruer formula's prediction of the energy in the tail of a distribution (due to correlated errors in the fit). The result carries obvious implications to estimates of preheat. Lastly, we consider the standard assumptions for FFLEX (that x-ray spectra are exponential, and that hot electron distributions are Maxwellian) and suggest new methods for analyzing hard x-ray data at the National Ignition Facility. This work includes a more general analysis routine for FFLEX, and a new method for relating x-ray spectra and hot electrons. The result is a more developed understanding of the accuracy of FFLEX measurements, and several improvements to the tool(s) and technique(s) used in FFLEX data analysis. LLNL-ABS-412183*.

[1]. R. Drake, R. Turner, B. Lasinski, E. Williams, K. Estabrook, W. Kruer, and E. Campbell. X-ray emission caused by Raman scattering in long-length-scale plasmas. Physical Review A. Volume 40. Number 6. Pgs. 3219 – 3225.

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

39th Annual Anomalous Absorption Conference
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June 14-19, 2009

Nonlinear behavior of the Two Plasmon and High Frequency Hybrid Instabilities*

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[1]Department of Physics & Astronomy, University of California, Los Angeles
[2]Polymath Research Inc., Pleasanton, CA
[3]Department of Electrical Engineering, University of California, Los Angeles

We use the particle-in-cell code OSIRIS to study the large wave amplitude nonlinear limit of the $2w_p$ and HFHI [1,2] instabilities near the quarter critical density. Near threshold the observed plasmon spectra is dominated by absolute modes. For intensities greater than roughly 5 times the absolute threshold convective modes are present at lower densities. Results from simulations in which the laser is adiabatically turned on will also be presented. The saturated levels of the absolute modes are similar whether near to far above threshold. We have begun to study the role of the EPW turning points in setting convective gain levels above that predicted by the Rosenbluth model, and the possible enhancement (or diminution) of the growth rate of some modes due to the change of the distribution function caused by more unstable modes that precede them. We will also report on the long time behavior of $2w_p$, modifications to the electron distribution function, hot electron production and transport, laser absorption, pump depletion, mobile ions, and wave-wave interactions.

[1] B. B. Afeyan, E. A. Williams, Phys. Plas., 4, 3827 (1997).
[2] ibid. p. 3845. B. B. Afeyan, E. A. Williams, **75**, 4218 (1995).

*Work supported by DOE and NSF.

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$3/2\ w_0$ Emission from the LDI Langmuir Waves Excited in the Nonlinear Saturation of the Two Plasmon Decay Instability*

David Russell[1], Don DuBois[1,2], Hoanh Vu[3], J. Myatt[4], W. Seka[4], A.V. Maximov[4], and R.W. Short[4]
[1]Lodestar Research Corporation. Boulder, CO 80301
[2]Also at Los Alamos National Laboratory, Los Alamos, NM 87545
[3]University of California at San Diego, La Jolla, CA 920930407
[4]Laboratory for Laser Energetics, University of Rochester, Rochester, NY 14623

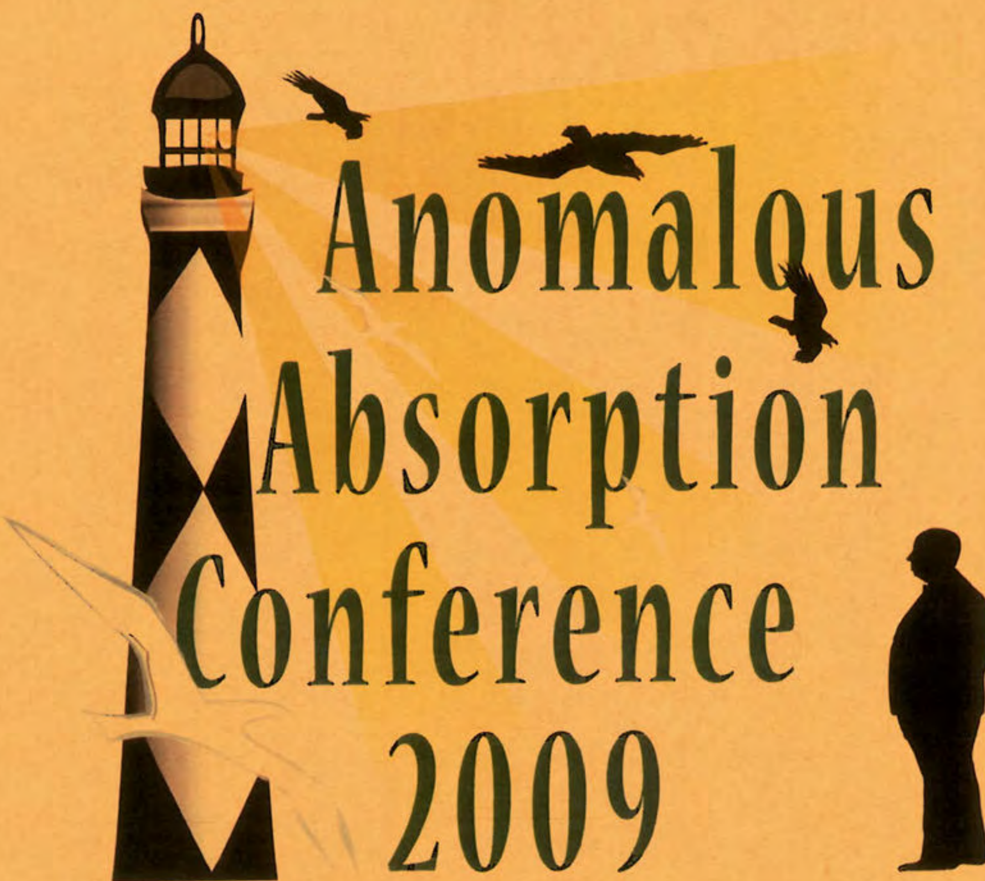
The $3/2\ w_0$ emission current results from Thomson upscatter of the laser light from Langmuir waves (LWs) exited by the two plasmon decay (TPD) instability [1]. It is well known that the primary LWs from TPD cannot couple directly (locally) to the emitted $3/2\ w_0$ light but it was customarily believed that propagation in the density gradient could bring the LWs to the correct matching conditions for $3/2\ w_0$ emission. In 2D Zakharov model simulations we can study the competition between the linear propagation of LWs in a density gradient and the nonlinear saturation of TPD due to the Langmuir decay stability (LDI) of the primary LWs. (The parametric decay of the primary LW into a secondary LW and an ion acoustic wave.) The propagation of primary and secondary LWs in the density gradient can be studied in detail. The results [1,2] show that direct coupling of the secondary LWs resulting from the Langmuir decay stability (LDI) of the primary LWs is possible. Even in a density gradient the LWs produced by LDI couple much more efficiently to the $3/2\ w_0$ light than the primary TPD waves [2]. The spectrum of the $3/2\ w_0$ light has the familiar two peaked form seen in many experiments [3]. The coupling to the secondary LDI waves seems to be essential , at least for a single laser beam parallel to the density gradient, to explain the observations. For sufficiently high electron temperatures only forward $3/2\ w_0$ emission is possible. We also present $3/2\ w_0$ emission spectra for cases of two oblique laser beams, motivated by the geometry of OMEGA experiments, in an initial linear density profile.

[1] D.F. DuBois, D.A. Russell,and H.A. Rose , PRL 74, 3983 (1995)
[2] D.A. Russell, and D.F. DuBois, PRL 86, 428 (2001)
[3] See e.g. Seka *et al.*, earlier paper in this conference

*Research supported by contract # DEFC5208NA28302 from LLE.

ORAL SESSION 2

Rad Hydro / LPI II



June 16, 2009

Tuesday
Chair - D. Callahan

N. B. Meezan ◆ J. L. Kline ◆ R. E. Olson ◆ E. Williams ◆ D. D.-M. Ho ◆ M. J. Schmitt ◆ C. K. Li ◆ P. Amendt

39th Annual Anomalous Absorption Conference
Bodega Bay, CA
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3D Radiation Hydrodynamics Simulations of NIF Hohlraum Energetics Experiments

N. B. Meezan, O. S. Jones, J. L. Milovich, D. H. Munro, D. E. Hinkel,
E. A. Williams, M. J. Edwards, M. M. Marinak, S. H. Glenzer and L. J. Suter

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7000 East Avenue, Livermore, CA 94550, USA

Recently, a number of experiments at the OMEGA laser facility have tested the capabilities of pF3D to predict the propagation of laser light through millimeter scale hot underdense plasma. The SRS and SBS reflectivity and the fraction of transmitted light have predicted the measured values with surprising success given the fact that some well known kinetic and fluid nonlinear effects have been omitted from the simulations. The success extends to the spectra of the transmitted and reflected light and to the distribution of light across the collection optics. The effect of polarization smoothing (PS) and smoothing-by-spectral-dispersion (SSD) on SRS and SBS was also predicted successfully, even predicting no effect in some cases. Recently the f-number scaling of the SRS reflectivity was measured to agree with pre-shot predictions. The key enabling factors for this predictive capability were an extensive rad-hydrodynamics design validated by Thomson scattering, use of the actual measured boundary conditions for the laser (phase plates, smoothing techniques) and access to routine teraflop computing power to allow full three dimensional simulations.

We will examine if the plasma parameters for the OMEGA experiments are in a parameter range where nonlinear effects are minimal and to what extent that is also true for the predicted NIF plasma parameters. Simple nonlinear models of some kinetic nonlinearities will be applied to the results.

*This work 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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Vacuum Hohlraum energetic experiments on the National Ignition Facility*

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K. Widmann, S. H. Glenzer, D. E. Hinkel, E. A. Williams, L. J. Suter, R. Berger, D. A. Callahan, E. Dewald, L. Divol, S. N. Dixit, D. Froula, C. A. Haynam, D. H. Kalantar, O. L. Landen, S. Le Pape, B. J. MacGowan, N. B. Meezan, J. Moody, J. Ralph, M. D. Rosen, M. B. Schneider, R. J. Wallace, and B. K. Young
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R. E. Olson
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Albuquerque, NM, 87185, USA

Results from vacuum hohlraum energetics experiments on the National Ignition Facility using a subset of NIF's 192 beams are presented. In these experiments, the scaling of radiation temperature for conventional gold hohlraums as well as gold hohlraums lined with a thin gold-boron liner was measured. These experiments are the first test of hohlraum drive scaling at ~ 70% of full-NIF scale. We show how these results compare with scalings developed on predecessor facilities at a fraction of the laser energy being used here.

In NIF ignition hohlraums, one of the mitigation strategies for Stimulated Brillouin Scattering is to mix boron into the inner 0.6 um of the Au hohlraum wall. These experiments will also test if, as predicted by simulations, there is no anomalous degradation of the radiation temperature due to the gold-boron liner. In addition, the intensity of the 30° cone beam diagnosed by the full aperture backscatter station is planned to be varied to observe effects of the boron on Stimulated Brillouin Scattering.

This work performed under the auspices of the U.S. Department of Energy by Los Alamos National Laboratory under contract DE-AC52-06NA25396, by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344, and by Sandia National Laboratory under contract DE-AC04-94AL85000.

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X-ray conversion efficiency in low-Z and mid-Z lined hohlraum targets *

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[1]*Sandia National Laboratories, Albuquerque, New Mexico*
[2]*University of Rochester Laboratory for Laser Energetics, Rochester, NY*
[3]*Lawrence Livermore Laboratory, Livermore, California*

Measurements of x-rays and backscatter from laser-driven hohlraum targets with thin CH and Cu liners are compared to measurements from unlined Au-wall hohlraums in order to determine time-resolved variations in x-ray conversion efficiency and x-ray spectra. The experiments were performed at the University of Rochester Omega Laser Facility. The key diagnostics included Dante, XRFC, FABS, and SOP. Most of the experiments analyzed here used a 2 ns square pulse in drive beams that heated the hohlraums to peak radiation temperatures in the range of 160-200 eV. It is found that the inferred x-ray conversion efficiencies can reach levels as high as 85% in unlined Au-wall hohlraums, but can be reduced to as low as 50% in CH-lined hohlraums. This, of course, results in a marked reduction in the measured hohlraum radiation temperature. If the CH or Cu liner is thin enough, the x-ray conversion efficiency rises during the latter stages of the experiment, reaching final x-ray conversion efficiency and radiation temperature levels that approach those of an unlined hohlraum. Dante predictions generated from the post-processing of Lasnex simulations are compared to the experimental data to demonstrate that the basic behavior of lined hohlraums can be understood within the context of the Lasnex code and its associated physics packages.

*Sandia is a multiprogram laboratory operated by the Sandia Corporation, a Lockheed Martin Company, for the U.S. Department of Energy under Contract No. DE-AC04-94AL85000.

39th Annual Anomalous Absorption Conference
Bodega Bay, CA
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Modeling Stimulated Brillouin Scattering in NIF Vacuum Hohlraum Experiments

Ed Williams, Denise Hinkel, Bert Still
Lawrence Livermore National Laboratory

Rick Olson
Sandia National Laboratory

John Kline
Los Alamos National Laboratory

In preparation for the NIF ignition campaign, a series of 96-beam shots are planned, firing the 30 and 50 degree cone beams into empty gold hohlraums. Their primary purpose is to qualify DANTE, the filtered X-ray diode radiation temperature diagnostic, and to get an initial look at hohlraum energetics on the NIF scale. Backscatter diagnostics, limited to a single 30 degree beam, are expected to be available, giving us an opportunity to test our LPI modeling. In addition to scaling with laser energy, we intend to test the use of a gold-boron coating on the inside of the hohlraum to reduce SBS backscatter by increasing the ion Landau damping of the ion acoustic waves.

We use LASNEX to simulate the hydrodynamic evolution of the hohlraum plasma. Steady state gains are computed from these profiles using our diagnostic NEWLIP. These are used to suggest appropriate backscatter simulations to be performed with pF3D, a massively-parallel code that couples paraxial light propagation with fluid models of the stimulated plasma and ion waves evolving on a background plasma.

We describe the results of these simulations and compare them with the results (if available) of the experimental campaign.

*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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LIFE hohlraum with one-sided illumination and the limit on illumination asymmetries for fast-ignitor capsules

D. D.-M. Ho, M. Tabak, G. B. Zimmerman, P. A. Amendt, D. S. Clark, and J. A. Harte
Lawrence Livermore National Laboratory

The proposed Laser Inertial Fission-Fusion Energy (LIFE) system has a fission blanket energy multiplier of 4 – 8x which reduces the required fusion target gain. Consequently, the operating regime for fusion gain versus laser energy space is expanded over conventional IFE, and the use of smaller laser drivers becomes possible. Both the fast ignition and the hot-spot ignition options with a "NIF"-like geometry can be used in LIFE. This presentation has two parts. The first part describes the design of the hohlraum and the second part presents the calculations performed to find the limits for the radiation asymmetries for a typical fast-ignitor capsule.

For the fast-ignition concept, a hohlraum with low laser-incidence angle (e.g., between 10° to 20°) compression laser beams coming in from one direction is designed using the viewfactor code GERTIE. Compression laser beams entering the hohlraum from one side eliminates the need for the second laser entrance hole (LEH) on the opposite end of the hohlraum; otherwise, radiation coming out the second LEH can ionize the chamber gas and can potentially prevent the ignitor beam from forming a tight focus[1]. The potential for significant LPI is minimized in our design. Our proposed hohlraum configuration has a gain of about 30. The radiation symmetry provided by this hohlraum design easily meets the requirements for a typical fast-ignitor capsule (see below).

To find the limits on the radiation asymmetries for a fast-ignitor capsule, we performed a series of 2-D capsule-only LASNEX simulations with constant as well as time-dependent applied P_2 and P_4 asymmetries. We find that the fast-ignitor capsule is extremely tolerant to radiation asymmetries in comparison to typical hot-spot ignition capsule design. For example, a fast-ignition capsule can tolerate up 8% of constant P_2 and P_4 asymmetries, compared with < 1% for hot-spot design.

[1]Scott Wilks, private communication

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

39th Annual Anomalous Absorption Conference
Bodega Bay, CA
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Calculations of the implosion velocities of copper-doped beryllium capsules shot on the Omega laser*

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Livermore, CA, 94551

We have performed Lasnex calculations of the implosion velocities of thin-shell (~15μm thick) beryllium capsules that were shot at the Omega laser facility in 2008[1]. These capsules contained an internal layer that was doped with 2.1% (atomic fraction) copper. Initial simulations predicted an implosion velocity that was significantly faster than that seen in the experiments. Subsequent simulations were performed to determine the effect of various concentrations of copper on the implosion velocity of these capsules. Results indicated that an unrealistically high concentration of Cu (1.5%) in the outer layer of the capsule (where no Cu was deposited or should have diffused) was required to slow the simulated capsule implosion velocity to a value close to the experimentally observed value. Changes to other physics-based assumption made in the simulations were unable to significantly affect implosion speed. These results were further compounded by the fact that a comparison of the Dante hohlraum temperature measurements with simulated Dante diagnostic temperatures showed that the simulation temperatures were slightly cooler than the experimentally observed temperatures (which makes the comparison worse!). However, further investigation[2] has revealed that the outer undoped layer of the capsules contained 4% oxygen (in the "pure" Be) caused by entrainment during the Be deposition process. This concentration is significantly higher that what was assumed in the simulations. A description of the previous results, and new calculations that include the effect of the 4% O, will be shown.

* This work supported by US DOE/NNSA, performed at LANL, operated by LANS LLC under Contract DE-AC52-06NA25396.

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[1] R. K. Kirkwood, J. Milovich, D. K. Bradley, M. J. Schmitt, S. R. Goldman, D. H. Kalantar, D. Meeker, O. S. Jones, S. M. Pollaine, P.A. Amendt, E. Dewald, J. Edwards, O. L. Landen and A. Nikroo, "Sensitivity of ignition scale backlit thin-shell implosions to hohlraum symmetry in the foot of the drive pulse" Phys. Plasmas **16**, 012702 (2009).

[2] Abbas Nikroo, General Atomics, San Diego, CA, personal communication.

39th Annual Anomalous Absorption Conference
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Pressure-driven, resistive interchange instabilities in laser-produced, high-energy-density plasmas

C. K. Li,[1] J. A. Frenje,[1] R. D. Petrasso,[1] F. H. Séguin,[1] P. A. Amendt,[2] O. L. Landen,[2] R. P. J. Town,[2] R. Betti,[3,4] J. P. Knauer,[3] D. D. Meyerhofer,[3,4] and J. M. Soures[3]

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[2]*Lawrence Livermore National Laboratory, Livermore, California 94550 USA*
[3]*Laboratory for Laser Energetics, University of Rochester, Rochester, New York 14623 USA*
[4]*Department of Mechanical Engineering, and Physics and Astronomy, University of Rochester, Rochester, New York 14623 USA*

Proton radiography has been used to study instabilities in plasmas generated by the interactions of laser with planar plastic foil. Time-gated images, made with 15-MeV protons, indicate that the outer structure of a magnetic field entrained in a hemispherical plasma bubble becomes distinctly asymmetric after the laser turns off. It is shown that such an asymmetry is a consequence of pressure-driven, resistive magneto-hydrodynamic (MHD) interchange instabilities. In contrast to the predictions made by ideal MHD theory, increasing plasma resistivity after laser turn-off allows for greater low-mode destabilization ($m > 1$) because stabilization by field-line bending is reduced. For laser-generated plasmas presented herein, a mode-number cutoff for stabilization, $m > \sim [8\pi\beta(1+D_m k_\perp^2 \gamma_{max}^{-1})]^{1/2}$, is found in the linear growth regime. The growth is measured and is found to be in reasonable agreement with model predictions.

The work was performed at the LLE National Laser User's Facility (NLUF), and was supported in part by US DOE (DE-FG52-07NA28059 and DE-FG52-06N826203), LLNL (B543881 and LDRD-ER 898988), and LLE (414090-G), The Fusion Science Center at University of Rochester (412761-G).

* Oral presentation preferred

Design of an indirect-drive non-cryogenic double-shell target driven by a 1ω Nd laser*

Peter Amendt, Jose L. Milovich, L. John Perkins and Harry F. Robey

Lawrence Livermore National Laboratory
Livermore CA 94551

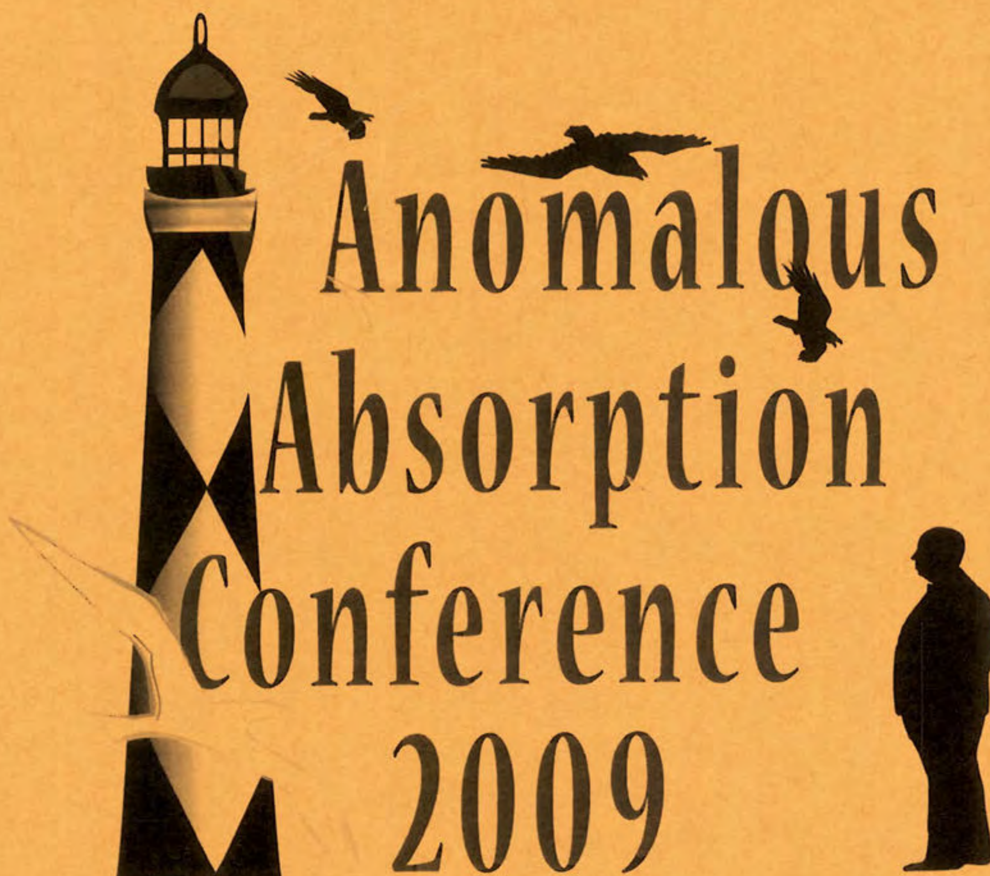
The challenge with current room-temperature double-shell ignition designs is maximizing the available energy at 3ω [1] for the needed margin to debilitating mix between the high-Z inner shell and the deuterium-tritium fuel. A new scheme is proposed that develops scaling-law relations to minimize potential SRS and SBS growth by using a quasi-impulsive laser drive. Ignition double shells do not require adiabat shaping or high-contrast pulse shapes, and are compatible with a quasi-impulsive laser drive. By utilizing large phase plates, $\approx 9\times$ lower intensity, and a relatively large vacuum hohlraum designed around a low drive temperature to accommodate the large laser focal spots, a promising regime is identified for 1ω operations. The attendant energy available is nearly $2\times$ larger than for 3ω, thereby increasing the performance margin for robust ignition. One-dimensional double-shell target designs driven at 175 eV that give in excess of 40 MJ are described. Ideas to further improve on these high yields are developed and described. A fall-line mix model that is normalized to the Omega-scale double-shell implosion database [2,3] is implemented for predicting the expected degree of yield degradation from mix $(\approx 2\times)$.

[1] P. Amendt, C. Cerjan, A. Hamza, D.E. Hinkel, J.L. Milovich and H.F. Robey, Phys. Plasmas **14**, 056312 (2007).
[2] P. Amendt, H.F. Robey, H.-S. Park *et al.*, Phys. Rev. Lett. **94**, 065004 (2005).
[3] H.F. Robey, P. Amendt, J.L. Milovich *et al.*, "Hohlraum-driven implosions of mid-*Z* (SiO_2) double-shell capsules on the Omega laser facility," submitted to Phys. Rev. Lett.

*Work performed under the auspices of U.S. Department of Energy by LLNS-LLC under Contract No. W-7405-Eng-48.

Invited Talk 2

Progress on Laser-Plasma Acceleration Using Spatially Tailored Plasmas



June 16, 2009

Tuesday

Chair – A. B. Langdon

✦ W. Leemans ✦

39th Annual Anomalous Absorption Conference
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Progress on laser-plasma acceleration using spatially tailored plasmas*

W.P. Leemans,[1] E. Esarey,[1] C.G.R. Geddes,[1] Cs. Toth,[1] C.B. Schroeder,[1] K. Nakamura,[1] A.J. Gonsalves,[1] D. Panasenko,[1] E. Cormier-Michel,[1] G.R. Plateau,[1,2] C. Lin,[1,3]
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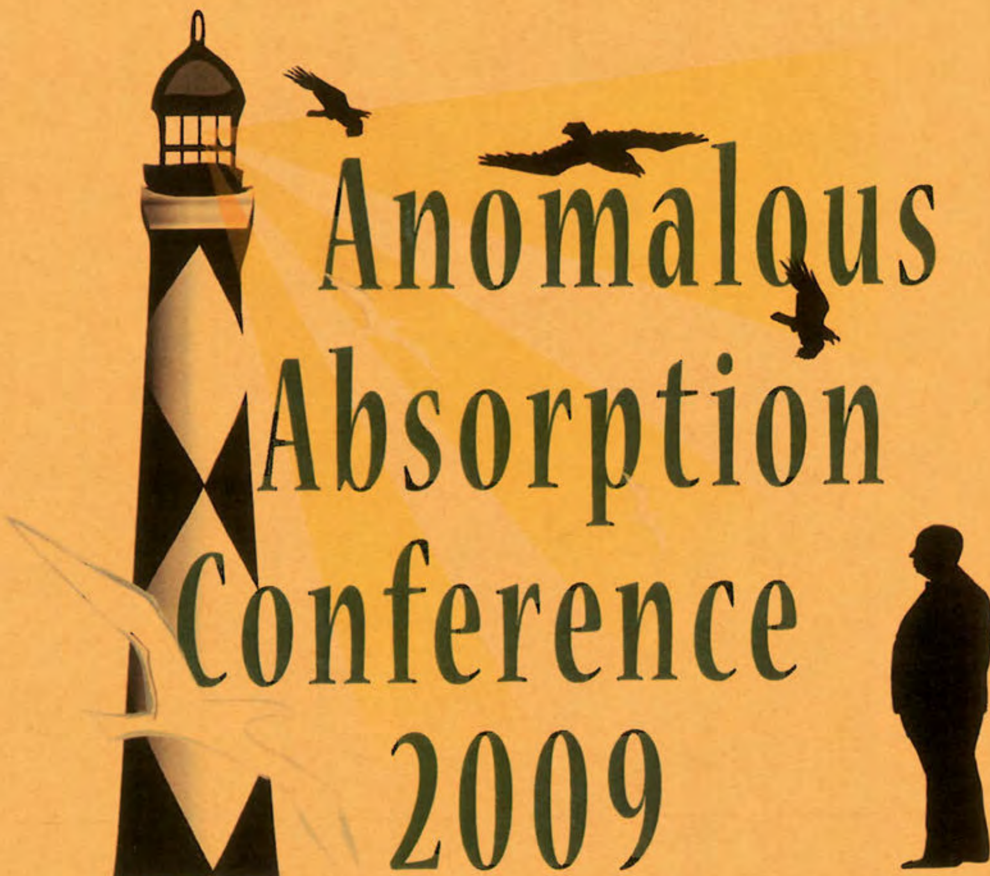
[3]*Peking University, Beijing 10087, China*

Progress on experiments at Lawrence Berkeley National Laboratory is given on down-ramp injection and on acceleration in capillary discharge plasma channels, which use longitudinal and transverse shaping of the plasma density profile, respectively. Control of trapping in a laser-plasma accelerator using plasma density down-ramps produced electron bunches with absolute longitudinal and transverse momentum spreads more than ten times lower than in previous experiments (0.17 and 0.02 MeV/c FWHM, respectively) and with central momenta of 0.76 ± 0.02 MeV/c, stable over a week of operation. Experiments were also carried out using a 40 TW laser interacting with a hydrogen-filled capillary discharge waveguide. For a 15 mm long, 200 μm diameter capillary, quasi-monoenergetic bunches up to 300 MeV were observed. By detuning discharge delay from optimum guiding performance, self-trapping was found to be stabilized. For a 33 mm long, 300 μm capillary, a parameter regime with high energy bunches, up to 1 GeV, was found. In this regime, peak electron energy was correlated with the amount of trapped charge. Simulations show that bunches produced on a down-ramp and injected into a channel-guided LWFA can produce stable beams with 0.2 MeV/c-class momentum spread at high energies.

* This work was supported by the U.S. Department of Energy under Contract No. DE-AC02-05CH11231.

POSTER SESSION 2



June 17, 2009

Wednesday

P. Amendt ✦ J. Hittinger ✦ S. Dupierreux ✦ C. DiStefano ✦ E. S. Dodd ✦ J. E. Fahlen ✦ S.M. Finnegan ✦ W. L. Kruer
P.-E. Masson-Laborde ✦ M. V. Patel ✦ D. Pesme ✦ M. D. Rosen ✦ D. J. Strozzi

39th Annual Anomalous Absorption Conference
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Simulations of plasma flows in vacuum hohlraums: Can we explain a commonly observed jet-like phenomenon?

P. Amendt, J.L. Milovich, S.H. Glenzer, H.-S. Park, and R.P.J. Town,
Lawrence Livermore National Laboratory
C.K. Lai and R.D. Petrasso
Institute of Technology Cambridge, MA

Understanding the plasma flows in hohlraums is relevant to indirect-drive capsule implosions. One important aspect of hohlraum dynamics has been little studied: self-generated electric and magnetic fields. Early Thomson scattering experiments on the Nova laser showed ≈1 MG fields localized near the laser spots on the hohlraum walls [1]. Recent experiments with 14.7 MeV proton backlighting at the Omega laser facility have also inferred such magnetic field strengths [2]. These fields, in addition to self-generated electric fields, could significantly alter electron heat transport and plasma conditions to modify our predictions of laser-plasma interactions and their effects on hohlraum x-ray drive and symmetry. In both experiments [1,2] radial, jet-like, supersonic features between the laser spots were observed to converge on the hohlraum symmetry axis. The fast evolution of these structures has not been satisfactorily explained with two-dimensional (2-D), single-fluid, radiation hydrodynamics simulations. A study with integrated 3-D hohlraum simulations is undertaken to help assess the potential role of self-generated fields in understanding these generic and prominent features of vacuum hohlraum experiments.

[1] S.H. Glenzer *et al.*, Phys. Plasmas **6**, 2117 (1999).
[2] C. K. Li *et al.*, submitted to *Phys. Rev. Lett.* (2009).

†This work performed under the auspices of the Lawrence Livermore National Security, LLC (LLNS) under Contract No. DE-AC52-07NA27344 and supported by LDRD-08-ERD-062.

39th Annual Anomalous Absorption Conference
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VALHALLA: An adaptive, continuum Vlasov code for laser plasma interaction *

J. Banks, J. Hittinger, R. Berger, B. Cohen
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To expand the ranges of laser plasma experiments on the National Ignition Facility, a better understanding of the nonlinear behavior of laser plasma instabilities, and in particular, thresholds for the onset of nonlinear behavior, is required. Continuum Vlasov simulation is an approach well suited for this task. Continuum kinetic approaches do not suffer from the discrete noise of traditional particle methods, noise which can potentially mask essential physical effects, and therefore these methods naturally complement existing particle methods.

The primary difficulty with continuum Vlasov simulation is the computational cost. Full simulation of three-dimensional configuration space requires discretization in a six-dimensional phase space, with computational costs increasing geometrically with dimension. Consequently, there are few examples of Vlasov simulation for more than a single spatial dimension. In addition, standard semi-Lagrangian Vlasov discretizations fail to preserve particle conservation discretely and positivity of the distribution function.

We currently are developing a continuum Vlasov code as part of the VALHALLA (Vlasov Adaptive Limited High-order Algorithms for Laser Applications) project. To address the issue of computational cost, we are using high-order finite volume discretizations with block-structured adaptive mesh refinement (AMR). This approach reduces the number of degrees of freedom by concentrating the mesh in isolated regions of high variation, such as in the vicinity of wave-particle resonances, and reduces the number of degrees of freedom required to obtain a constant level of error. In addition, the finite-volume approach naturally conserves particles and is amenable to many techniques developed to prevent unphysical oscillations and to preserve solution positivity. We will present the algorithms developed for VALHALLA and initial results from the currently implemented single-species, 2D adaptive Vlasov-Poisson code.

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

39th Annual Anomalous Absorption Conference
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Laser plasma interaction experiments on LULI 2000

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[2]*Laboratoire pour l'Utilisation des Lasers Intenses, Ecole Polytechnique, Palaiseau, France*
[3]*Centre Lasers Intenses et Applications, Université Bordeaux 1, CEA, CNRS, Talence, France*

We will present recent results obtained on LULI 2000 about laser plasma interaction in the nanosecond regime. We will describe the plasma parameters reached in these experiments and then report on the growth and saturation of stimulated Brillouin scattering (SBS) and stimulated Raman scattering (SRS) in the corresponding plasmas.

In these experiments, the two kJ beams of LULI 2000 are converted either to the second or third harmonics (300 J in 1.5 ns at both wavelengths). The first beam creates the plasma from a solid target or a gas jet. After 1.5 ns, the second beam interacts with the preformed plasma. The main diagnostic concerns the SBS and SRS scattered light monitored in the backscattered and near backscattered direction with time resolved spectral measurements and absolutely calibrated scattering levels. The transmitted light is also analysed with time resolved 2D images of the focal plane after propagation through the plasma. In the solid target experiment, the SBS is observed to be saturated either at 2 or 3ω with equivalent backscattering levels of 10% in the incident cone. The light scattered outside the cone (with twice the aperture) is also shown to saturate with ~ 8 % scattered outside the cone at both wavelengths. In the gas jet experiment performed at 2ω, the SRS is observed to be saturated with a backscattering level increasing when the density is increased.

The results obtained in these two experiments will be presented. Our interpretation of the SBS and SRS growth and saturation will be presented.

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Spike morphology in blast-wave-driven instability experiments relevant to supernovae*

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University of Michigan

J. F. Hansen
Lawrence Livermore National Laboratory

J. Knauer
University of Rochester

D. Arnett, C. Meakin
University of Arizona

T. Plewa
Florida State University

N. Hearn
National Center for Atmospheric Research

This presentation describes experiments performed on the Omega laser exploring the 3D Rayleigh-Taylor instability at a blast-wave-driven interface. These experiments are well scaled to the He-H interface during the explosion phase of SN1987A. Approximately 5 kJ of laser energy are used to create a planar blast wave in a plastic disk, which is then accelerated into lower-density foam. These circumstances induce the Rayleigh-Taylor instability. The plastic disk has an intentional pattern machined at the plastic/foam interface. This seed perturbation is three-dimensional with a basic structure of two orthogonal sine waves with a wavelength of 71 μm and amplitude of 2.5 μm. Interface structure has been detected under these conditions using dual, orthogonal radiography. Some of the resulting data will be shown. Also, recent advancements in x-ray backlighting techniques have greatly improved the resolution of the x-ray radiographic images. Under certain conditions, experimental radiographs show some mass extending from the interface to the shock front. The next experiment will further examine these mass extensions by varying the amplitude of the seed perturbation as well as by observing the evolution of the instability at earlier times.

*This research was supported by the DOE NNSA under the Predictive Science Academic Alliance Program by grant DE-FC52-08NA28616, the Stewardship Sciences Academic Alliances program by grant DE-FG52-04NA00064, under the National Laser User Facility by grant DE-FG03-00SF22021, and by the Stewardship Science Graduate Fellowship program.

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Simulations of direct-drive capsule experiments at OMEGA*

E. S. Dodd, J. F. Benage, G. A. Kyrala, I. L. Tregillis, D. C. Wilson, and F. J. Wysocki
Los Alamos National Laboratory, Los Alamos

W. Seka and V. Yu. Glebov
Laboratory for Laser Energetics, University of Rochester

J. A. Frenje
Plasma Science and Fusion Center, Massachusetts Institute of Technology

The implosion dynamics and yield of an ICF capsule can be greatly affected by the inclusion of high-Z material in the fuel. If the material is either intentionally mixed into the fuel as a diagnostic [1], or if mixing of the shell occurs due to hydrodynamic instabilities, then calculations must be verified. To better understand the effects of high-Z materials on burn, a series of experiments have been fielded at the OMEGA laser [2]. The targets are glass shells with an outer diameter of ~920 μm and a thickness of ~4 μm, and are filled with a mixture of D_2 and ^3He. They may also be filled with controlled amounts a dopant, Ar, Kr, and/or Xe. These targets are then directly driven with a 1.0 ns (0.6 ns) square laser pulse having a total energy of 23 kJ (13.8 kJ), and the data compared with yield and burn-temperature predictions from 1-d radiation-hydrodynamics calculations.

Our calculated yields are typically a factor of two greater than the measured yield (*e.g.* $Y_{meas} = 8.2\times10^{10}$ and $Y_{calc} = 2.0\times10^{11}$ for DD-neutrons), and the measured burn-weighted temperatures are higher than from calculation (*e.g.* T_i=5.3 keV versus T_i=4.2 keV). These discrepancies are consistent with the previous work of Takabe *et al.* [3]. Estimates for the amount of laser energy absorbed, using the method of Seka *et al.* [4], indicate that only 65% to 70% of the laser energy is absorbed. However, our calculations absorb 85% of the energy. The diagnostics also show two-plasmon decay for the 1.0 ns laser pulses but not for the 0.6 ns pulses, while the absorption discrepancy exists in both cases. In this talk, we will discuss the results of recent 1-d calculations where the input energy and electron-transport flux limiter have been varied to better match the data. Our calculations show that a multiplier on the energy of 0.75 and a flux-limiter of 0.10 gives a capsule yield of $Y_{calc}=1.1\times10^{11}$. Physical reasons for this discrepancy in the absorbed energy will be discussed, but no definitive answer has yet been reached. The importance of hot-electron pre-heat will also be discussed.

[1] G. A. Kyrala, D. C. Wilson, J. F. Benage, *et al.*, *HEDP* **3** 163 (2007).
[2] T. R. Boehly, R. S. Craxton, T. H. Hinterman, *et al.*, *Rev. Sci. Instrm.* **66** 508 (1995).
[3] H. Takabe, M. Yamanaka, K. Mima, *et al.*, *Phys. Fluids* **31** 2884 (1988).
[4] W. Seka, D. H. Edgell, J. P. Knauer, *et al.*, *Phys Plasmas* **15** 056312 (2008).

* Supported under the U. S. Department of Energy by the Los Alamos National Security, LLC under contract DE-AC52-06NA25396.

39th Annual Anomalous Absorption Conference
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Finite-Size Effects in Electron Plasma Waves and Their Application to SRS*

J.E. Fahlen, B.J. Winjum, T. Grismayer, F.S. Tsung, V.K. Decyk, W.B. Mori
University of California, Los Angeles

Particle-in-cell (PIC) simulations of stimulated Raman scattering (SRS) in one and two dimensions indicate that the daughter electon plasma waves are finite in their longitudinal and transverse extent. Though previous work has examined many plasma wave nonlinearities, including nonlinear frequency shifts, sideband instabilities, pump depletion, and other, finite size effects have often been overlooked. In this poster we present electrostatic PIC simulations used to study plasma wave propagation in detail. At low amplitudes, the waves damp at the usual Landau damping rate. As the amplitude increases, particles trap and novel effects associated with the wave's finite size occur. In 1D, wave packets 'etch' away at a constant rate that depends on their amplitude and wavelength. Finite waves in 2D tend to localize around their center due to an energy imbalance between the trapped particles and the wave's electric field. We compare these results with fully electromagnetic simulations to show their importance for SRS reflectivity.

* This work is supported by DOE under Grant Nos. DE-FG52-03-NA00065, DE-FG52-06NA26195, and DE-FG02-03ER54721, and some simulations were carried out on the DAWSON Cluster supported under NSF grant No. NSFPhy-0321345.

Effects of binary particle collisions on the onset of backward stimulated Raman scattering of laser in kinetic regime *

S. M. Finnegan, L. Yin, B. J. Albright, K. J. Bowers•, and J. L. Kline

Los Alamos National Laboratory, Los Alamos, NM 87545.

The onset of backward stimulated Raman scattering (SRS) in a single laser speckle is examined in the kinetic regime using 1D and 2D VPIC [1] simulations. A binary particle collision model [2] has been implemented in VPIC, which allows the inclusion of both like-particle (i.e, electron-electron and ion-ion) and electron-ion collisions, the effects of which have been isolated and studied independently. To ensure the validity of the collisional model, this initial study focuses on the onset of SRS at relatively low laser intensity. Collisional effects on SRS are isolated from the effects of stimulated Brillouin scattering (SBS) by increasing the ion mass to suppress ion acoustic wave growth. Under conditions relevant to short-pulse (~3 ps at FWHM), single-speckle experiments at Trident [3], the SRS reflectivity measured as a function of the speckle intensity shows a sharp onset at a threshold intensity and a saturated level at higher intensity, consistent with the experimental results. In the presence of both like-particle, and electron-ion collisions, an increase in the SRS onset threshold intensity is observed in 1D, along with a reduction in the saturated reflectivity. Regimes of weak and strong collisionality are identified and collisional results are compared with those obtained in the collisionless limit [4].

[1] K. J. Bowers, B. J. Albright, L. Yin, B. Bergen, and T. J. T. Kwan, Phys. Plasmas, 15, 055702 (2008).
[2] T. Takizuka and H. Abe, J. Comput. Phys., 25, 205 (1977).
[3] J. L. Kline, D. S. Montgomery, L. Yin et al., J. Phys.: Conf. Series, 112, 022042 (2008); J. L. Kline, D. S. Montgomery, C. Rousseaux et al., Lasers Part. Beams, 27, 185 (2009).
[4] L. Yin, B. J. Albright, K. J. Bowers, J. L. Kline, D. S. Montgomery, K. A. Flippo, and H. A. Rose, J. Phys.: Conf. Ser., 112, 022033 (2008).

*This work was performed under the auspices of the US DOE.
•Guest Scientist. Currently with D. E. Shaw Research, LLC, New York, NY 10036.

39th Annual Anomalous Absorption Conference
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Reducing laser plasma interaction surprises in ignition-scale hohlraums*

William L. Kruer
University of California, Davis

The laser plasma interaction physics expected for NIF hohlraums has been analyzed in impressive detail[1,2]. However, since the coupling physics is complex and excellent control of its temporal and spatial dependence is required, it is prudent to continue to search for potential surprises. A number of effects not usually included in the mainline calculations are here examined. These include stimulated scattering at an angle, side scattering, the $2\omega_{pe}$ instability, and multiple beam effects. More attention is also focused on the heated electron energy distributions as well as on the possibility of higher than expected effective temperatures due to the above mentioned processes. Finally, the sensitivity of the coupling physics to variations in plasma conditions due to uncertainties in the electron heat transport is discussed, as well as some noise level and shaped pulse issues.

1. D.E. Hinkel *et.al.*, Physics Plasmas 15, 056314 (2008)
2. P. Michel *et.al.*, Physics Plasmas 16, 1 (2009), and references therein

*Part of this work 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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Kinetic Simulations of Stimulated Raman Scattering

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Results of PIC simulations of the stimulated Raman scattering in one and two spatial dimensions are discussed. 2D simulations results at large k_L/k_D values are consistent with results by Yin et al. Phys. Plasmas 15, 013109 (2007). However, our interpretation differs in stressing the SRS reflectivity randomness due to frequency shift and transverse modulations of Langmuir waves by (i) Weibel instability due to the current of trapped particles and (ii) trapped particle modulational instability. Randomness due to the frequency shift is responsible for the first saturation of SRS. In 1D PIC simulations in inhomogeneous plasmas we have studied the interplay between trapped particle nonlinear frequency shift and plasma density inhomogeneity.

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Assessing the sensitivity of ICF hohlraum conditions to NLTE opacity modeling*

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Michael M. Marinak, and Laurance J. Suter
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HYDRA [1] is a multi-physics, 2D/3D radiation hydrodynamics design code that is routinely used to simulate inertial confinement fusion (ICF) and high-energy density physics (HEDP) experiments. We have recently expanded HYDRA's NLTE opacity suite by installing a new in-line detailed configuration accounting (DCA) atomic kinetics package. HYDRA-DCA incorporates the kinetics and screened hydrogenic models from CRETIN [2]. This complements HYDRA's existing average-atom model NLTE package (XSN [3]), while allowing the flexibility to evolve populations spanning more levels than modeled in XSN and to use externally generated models (energy levels, transition rates) of arbitrary complexity. Because an in-line model has to strike a balance between accuracy and computational expense, it is encouraging that we are already able to exploit the inherent parallelism in the atomic kinetics to run production 2D simulations using DCA.

XSN and DCA results obtained from HYDRA simulations of laser irradiated hohlraums highlight the sensitivity of the hohlraum conditions (e.g. radiation temperature) to the NLTE model used as well as to the simulation parameters associated with each model. Detailed comparisons are made both for 1D (spherical) and 2D (cylindrical) hohlraums.

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In the presence of a ion kinetic effects

D. Pesme(1) and C. Riconda(2)
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We reconsider the stability of a "mother" Ion Acoustic Wave (IAW), characterized by its amplitude Φ_m. In the context of SBS, the mother wave is the IAW excited by SBS. The stability analysis of an IAW mother wave has been carried out by various authors in the past [1,2,3] in the context of an IAW fluid type nonlinearity. The fluid type nonlinearity leads essentially to a decay instability, the growth rate of which scales like $|\Phi_m|$, and to a modulational instability, the growth rate of which scales like $|\Phi_m|^2$.

In the present contribution, we reconsider the stability of a mother IAW by including, in addition to the fluid-type nonlinearity, the ion kinetic effects, in the limit where they can be modeled by a nonlinear frequency shift $\delta\omega_{nl}$ scaling like $\delta\omega_{nl} \propto |\Phi_m|^{1/2}$. This part of our stability analysis generalizes, to IAWs and in a multidimensional geometry, the one-dimensional stability analysis of an electron plasma wave in the presence of electron kinetic effects [4]. We find in the case of an IAW, that the ion kinetic effects give rise to a modulational instability, characterized by a wave number transverse to the mother wave direction, thus leading to the filamentation of the mother IAW.

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The curiously small spot size (in 3 keV x-rays) from a larger spot laser irradiance*

M.D. Rosen, R. A. London, M.B. Schneider, S. Dixit, D. S. Bailey, and W. L. Kruer
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A gold/boron disk was irradiated by a quad of NIF beams. The expected laser spot size was about 1100 microns FWHM in diameter. The 1 ns pulse had an average irradiance of 1.2 E+14 W/sq cm. The observed x-ray signal (~ 3 kev x-rays) had a considerably narrower width (about 750 microns). We have explored various scenarios to explain this. This paper concentrates on studying various non-LTE models to see what affect they have on the gross radiative losses and hence the temperature of the emitting regions, and whether or not that affects the x-ray FWHM. It will also include an assessment of what LPI phenomenon may be operating here.

Poster preferred

* This work 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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Electron Transport Simulations for Fast Ignition on NIF

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We present simulations of the transport of, and energy deposition by, a beam of relativistic electrons traversing a fuel assembly relevant for fast ignition. The simulation is done with the hybrid-PIC code LSP [1], run with the direct-implicit algorithm in cylindrically-symmetric (r-z) geometry. The fast electrons are modeled with standard implicit PIC, while the dense, cold background species are treated with implicit fluid particles (that carry an internal energy and temperature). Collisions of fast electrons off background species are handled with a relativistic, grid-based model similar to that of Manheimer [2] and Lemons [3]; the formulae for energy loss and angular scattering are those of Davies [4]. The manufactured fast-electron distribution function is chosen with an energy and angular spectrum motivated by explicit-PIC simulations of short-pulse laser-plasma interactions. The background electron relaxation rate, which determines the electrical conductivity, is found using the Lee-More-Desjarlais model [5, 6].

The dependence of fuel heating on system parameters, such as beam spot size and pulse length, fast electron distribution, and target material (and thus conductivity), will be explored. We have found that magnetic fields increase the deposition into the ignition region of the fuel target, as reported previously by others. A cryogenic DT and "warm" plastic (CD) target will be compared, both for beam parameters appropriate to a coupling experiment (~ 9 kJ of laser energy) and a full-scale ignition experiment (~45 kJ of laser energy) on NIF.

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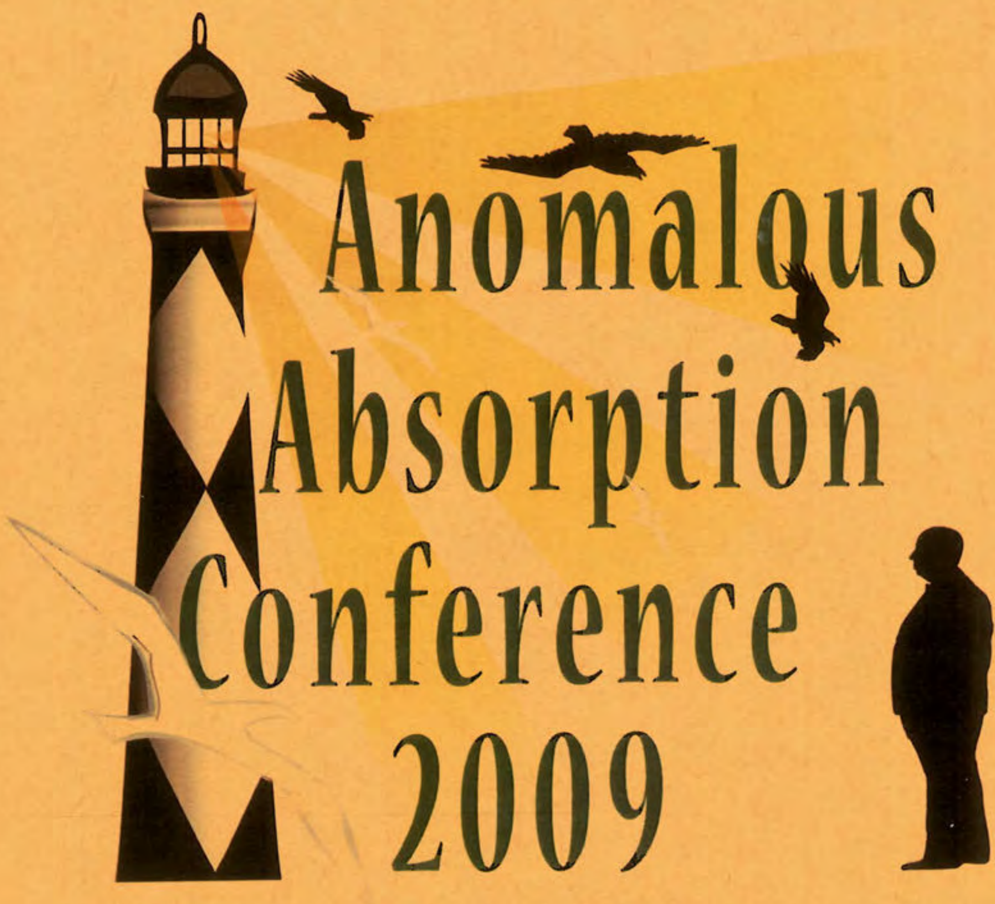
ORAL SESSION 3

Accelerator / Short-Pulse Physics



June 17, 2009

Wednesday

Chair - W. Kruer

C. G. R. Geddes ✦ E. Esarey ✦ A. Pak ✦ J. E. Ralph ✦ W. B. Mori ✦ C. B. Schroeder ✦ J. May ✦ S. J. Hughes ✦ C. Ren ✦ J. Tonge

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Multi-GeV laser wakefield accelerator stage and controlled injection simulations*

C.G.R. Geddes, E. Cormier-Michel, E. Esarey, C.B. Schroeder, Cs. Toth, and W.P. Leemans
Lawrence Berkeley National Laboratory, Berkeley, Caliorina 94720

D.L. Bruhwiler, J.R. Cary, B. Cowan, K. Paul, P. Stoltz, and C. Nieter
Tech-X Corporation, Boulder Colorado 80303

Laser-plasma-based particle accelerators promise more compact systems due to accelerating gradients on the order of 100 GV/m achieved via ponderomotive excitation of electron plasma waves. Collider and light source applications of these accelerators will likely require staging of controlled injection of multi-GeV accelerator modules to produce and maintain the required low emittance and energy spread. We present particle-in-cell simulations using the VORPAL framework of upcoming 10 GeV-class LWFA stages for the BELLA laser, towards eventual collider modules for both electrons and positrons [1]. Design of efficient few-hundred-MeV stages for Thomson radiation sources are also presented. Laser and structure propagation are controlled through a combination of laser channeling and self guiding. Electron beam evolution is controlled through laser pulse and plasma density shaping, and beam loading. This can result in efficient stages which preserve high quality beams. We also present results on controlled injection of electrons into the structure to produce the required low emittance bunches [2]. Tools for accurately modeling emittance and energy spread will be discussed [3].

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2. C.G.R. Geddes et al., PRL 2008.
3. E. Cormier-Michel et al, PRE 2008; C.G.R. Geddes et al, Proc. Adv Accel. Workshop 2008.

* This work was supported by the U.S. DOE Office of Science HEP including contract DE-AC02-05CH11231 and SciDAC, and by U.S. DOE NA-22, DARPA, and NSF

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Laser plasma acceleration with higher-order modes*

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D. Bruhwiler, B. Cowan
Tech-X Corporation, Boulder CO, 80303

Laser-plasma accelerators (LPAs) support field gradients on the order of 100 GV/m and recent experiments at LBNL have demonstrated the production of high quality electron bunches at 1 GeV using 40 TW laser pulses within a 3 cm long capillary discharge plasma [W.P. Leemans et al., Nature Phys. **2**, 696 (2006)]. LPAs can serve as compact accelerators for various applications such as drivers for x-ray free-electron lasers or modules for future colliders. For example, LBNL is pursuing a collider design based on 10 GeV modules driven by 40 J laser pulses that will operate in the quasi-linear wakefield regime (with a mildly nonlinear, nearly sinusoidal plasma wave), which has the advantage of being able to accelerate both electrons and positrons in a nearly symmetric fashion. Another advantage of the quasi-linear regime is that the focusing forces (transverse fields) of the plasma wave are proportional to the transverse gradients in the laser intensity profile. By controlling the transverse intensity profile through the use of higher-order laser modes, the focusing forces can be tailored. Focusing forces play an important role in determining the beam quality (e.g., emittance) and total charge of the accelerated bunch. Theory and particle-in-cell simulations show that higher-order modes can be used to tailor and reduce the transverse fields of the plasma wave, which subsequently improves the bunch quality.

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Investigation of Ionization Induced Trapping in a Laser Wakefield Accelerator*

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Controlling the trapping of electrons into laser generated plasma wakefields is an important step in obtaining a stable reproducible electron beam from a laser wakefield accelerator. Recent experiments at UCLA have focused on using the different ionization potentials of gases as a mechanism for controlling the trapping of electrons into an laser wakefield accelerator. The accelerating wakefield was produced using an ultra-intense ($I_o \sim 10^{19}$ W / cm^2), ultra-short ($\tau_{(FWHM)} \sim 45$ fs) laser pulses. The laser pulse was focused onto the edge of column of gas created by a gas jet. The gas was a mixture of helium and nitrogen. The rising edge of the laser pulse fully ionizes the helium atoms and the first five bound electrons of the nitrogen which are expelled by the laser to create a wake. Only at the peak of the laser pulse is it intense enough to ionize the most tightly bound electrons of nitrogen. These electrons are 'born' into a favorable phase space within the accelerating wakefield and are subsequently trapped and accelerated. The accelerated electrons were dispersed using a dipole magnet with a ~ 1 Tesla magnetic field onto a phosphor screen.

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700 MeV electrons from an 8.5 mm Self-Guided Laser Wakefield Accelerator*

J. E. Ralph[1,2], D. H. Froula[1], C. E. Clayton, T. Doeppner[1], K. A. Marsh, L. Divol[1], S. H. Glenzer[1], C. Joshi, P. Michel[1], J. P. Palastro[1], B. B. Pollock[1], A. E. Pak, and J. S. Ross

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Experimental results using a 200 TW, 60 fs laser pulse demonstrate acceleration of self-trapped electrons to a level of 730 MeV in an 8.5 mm Helium gas jet target. To achieve this degree of acceleration, the experiment was designed for matched self-guiding at a density of 2.5x1018 cm-3. Full 3D Particle-In-Cell simulations show excellent agreement with experimental results. Energy measurements relied on a unique two-screen method to eliminate error due to angular deviation of the electron beam. The threshold for self-trapping of electrons was found to be a strong function of the laser pulse power compared with the critical power for relativistic self-focusing.

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Laser wakefield acceleration: Recent developments in theory and simulation *

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UCLA
S. Martins, J. Vierira, R.A.Fonseca, L.O. Silva
IST

The extraordinary ability of space charge waves in plasmas to accelerate charged particles at gradients orders of magnitude greater than that in current accelerators has been well documented. The past five years has seen an explosion of experimental results on generating mono-energetic electron beams from 100 MeV to 1 GeV. The laser and plasma parameters span a wide parameter space and in most cases the wakes are inferred to be weakly nonlinear to fully nonlinear structures. Recently, a phenomenological theoretical framework for this regime was described (Lu et al. PRSTAB 10, 061301 2007). This theory identifies and clarifies the key physical mechanisms of laser wakefield acceleration (LWFA) in the blowout or "bubble" regime, including laser plasma matching condition, local pump depletion (photon deceleration), dephasing, self-guiding or matched channel guiding, beam loading and self-injection. Based on this understanding, design formulas for optimal acceleration to achieve stable real accelerator-like LWFA were described. These include how to choose the plasma density and length, laser matching spot size, and the estimated electron beam energy gain, the total beam charge that can be supported by the accelerating structure and the total energy conversion efficiency. In this talk, key concepts from this theory will quickly reviewed. We will also discuss the possibilities for output energy and charge using future laser systems based on both theory and PIC simulation results. The PIC simulations include using full PIC, Boosted frame PIC, and quasi-static PIC.

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Intense, short-pulse laser evolution and depletion in underdense plasma*

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We consider the evolution of relativistically intense laser pulses that resonantly excite large amplitude electron plasma waves. These plasma waves have relativistic phase velocities and can be used to accelerate charged particles. Laser-plasma accelerators can achieve accelerating gradients on the order of 100 GV/m via ponderomotive excitation of nonlinear electron plasma waves, providing compact accelerators for a wide variety of applications. The energy gain in laser-plasma accelerators is limited by the laser evolution, and, in particular, the depletion of laser energy via plasma wave excitation. Typically, the evolution of a resonant laser pulse proceeds in two phases. In the first phase of evolution, the pulse steepens, compresses, and frequency red-shifts as energy is deposited in the plasma. The second phase occurs after the laser pulse reaches a minimum length at which point the pulse rapidly lengthens, losing resonance with the plasma. Expressions for the rate of laser energy loss, pulse steepening, and laser frequency red-shifting are derived and are found to be in excellent agreement with the direct numerical solution of the laser field evolution coupled to the plasma response [B.A. Shadwick, C.B. Schroeder, E. Esarey, Phys. Plasmas (2009)]. These processes are shown to have the same characteristic scale length (pump depletion length). In the highly-relativistic intensity limit, for nearly-resonant Gaussian laser pulses, this scale length is shown to be independent of laser intensity.

* This work was supported by the U.S. Department of Energy under Contract No. DE-AC02-05CH11231.

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On Electron Acceleration by High Intensity Lasers in Steep Density Gradients

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F. Fiuza, R. A. Fonseca, L. O. Silva
GoLP/IPFN, Instituto Superior Técnico, Lisbon, Portugal

C. Ren
University of Rochester

The energy spectrum of electrons generated at the laser-plasma interface by the ignition laser is of great interest in fast ignition. Ponderomotive scaling is usually assumed for the energy spectrum of these electrons, but the mechanism for the acceleration is still not well understood. We use the Particle-In-Cell code OSIRIS to model the interaction of high intensity lasers ($I>=5x10^{19}$ W/cm^2) with a sharp boundary of an over-critical plasma ($n>>n_c$).

We find that in 1D and s-polarized 2D cases (that is, in cases where the laser electric field is perpendicular to the simulation plane), absorption remains very low unless the plasma is preheated to temperatures T_e~100keV. In 2D p-polarized cases, the laser heats the front of the plasma, leading to further absorption. None of the commonly proposed absorption mechanisms – i.e., inverse Bremsstrahlung, JxB, Brunel – can account for the spectrum of forward accelerated electrons. Rather, these electrons gain energy when they randomly leave the plasma and interact with the incident and reflected radiation within half a laser wavelength of the target surface. Electrons which leave the plasma at high energies and at preferential angles gain the most energy. Results from particle tracking in the OSIRIS code, as well as with a simple 1D imposed-field model confirm this acceleration mechanism.

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Hot electron transport modelling with non-Spitzer resistivity using THOR

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Fast ignition Inertial Confinement Fusion (ICF) schemes, and many laser-driven High Energy Density Physics (HEDP) experiments, rely on the efficient propagation of an energetic electron beam through high density, partially ionised (and possibly strongly degenerate) matter. In the case of fast ignition, this beam must then deposit sufficient energy in the assembled fuel to achieve ignition.

The transport of the electron beam is strongly affected by the resistivity of the target material. This dictates the strength of the resulting return current which results in Ohmic heating, and is itself a function of the background temperature. Often the resistivity of the target is assumed to follow the classical Spitzer scaling (i.e. $\varepsilon \sim T_e^{-3/2}$, where T_e is the background electron temperature) for the whole range of temperatures encountered. This is known to be inappropriate at high densities and/or low temperatures. It has been shown experimentally that the resistivity scales linearly with T_e in the cold regime, and later enters a saturation regime with only weak temperature dependence.

Here we present results of simulations of FI relevant targets using the THOR fast electron transport code. In particular, the effects of various resistivity models on the heating profiles, degree of electron beam collimation, and electric and magnetic field structure are studied. These results are then compared for alternative resistivity models revealing differences in the evolution of the beam.

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PIC Simulations of Laser Channeling in Millimeter-Scale Underdense Plasmas for Fast Ignition

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T.L.Wang, J.Tonge, W.B.Mori, University of California, Los Angeles

A key issue for the fast ignition concept is to deposit the ignition pulse sufficiently close to the compressed fuel core without significant energy loss in the millimeter (mm) -long underdense plasma surrounding it. One proposed technique is to use a channeling pulse to produce a low-density channel to reduce the nonlinear interactions of the ignition pulse in the underdense region. We will present recent two-dimensional (2D) and three-dimensional (3D) particle-in-cell (PIC) simulation results for laser channeling in mm-scale underdense plasmas. The mm-scale 2D simulations show many new phenomena that were not present in previous 100 μm-scale experiments and simulations, including plasma buildup to above critical density in front of the laser, laser hosing/refraction, channel bifurcation and self-correction, and electron heating to relativistic temperatures. The channeling speed is much less than the linear group velocity of the laser. A scaling from the simulations shows, that low-intensity channeling pulses are preferred to minimize the required energy. Significant improvement of the transmission of the ignition pulse in a preformed channel has been demonstrated. The 3D PIC simulations, with reduced scale, show that the channeling speed is larger in 3D than in 2D due to stronger laser self-focusing. This work was supported by the U.S. Department of Energy under Grants No. DE-FG02-06ER54879, No. DE- FC02-04ER54789, No. DE-FG52-06NA26195, and No. DE-FG02-03ER54721. Simulations were carried out at the NERSC through an INCITE grant and on the UCLA DAWSON Cluster under Grant No. NSF-Phy-0321345.

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On the Advantages of Fast Ignition with Ultra-High Intensity Lasers

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GoLP/IPFN, Instituto Superior Técnico, Lisbon, Portugal

C. Ren
University of Rochester

One of the critical design constraints for fast ignition targets is the need to have a small cross section for the hot spot at the target core while delivering enough power to the hot spot with hot electrons of the proper energy range, ~ 1-3 MeV, to couple to the core. We use two-dimensional Particle-In-Cell simulations of isolated targets to investigate the feasibility of using 1μm ignition lasers with ultra-high intensities, up to $8x10^{20}$W/cm^2, for fast ignition. The self-consistent absorption of energy from an ultra-high intensity laser by overdense plasma and the subsequent energy transport through the collisionless overdense plasma, $\nu_{ei} < \omega_p$, of a 50μm radius isolated target, is explored in detail.

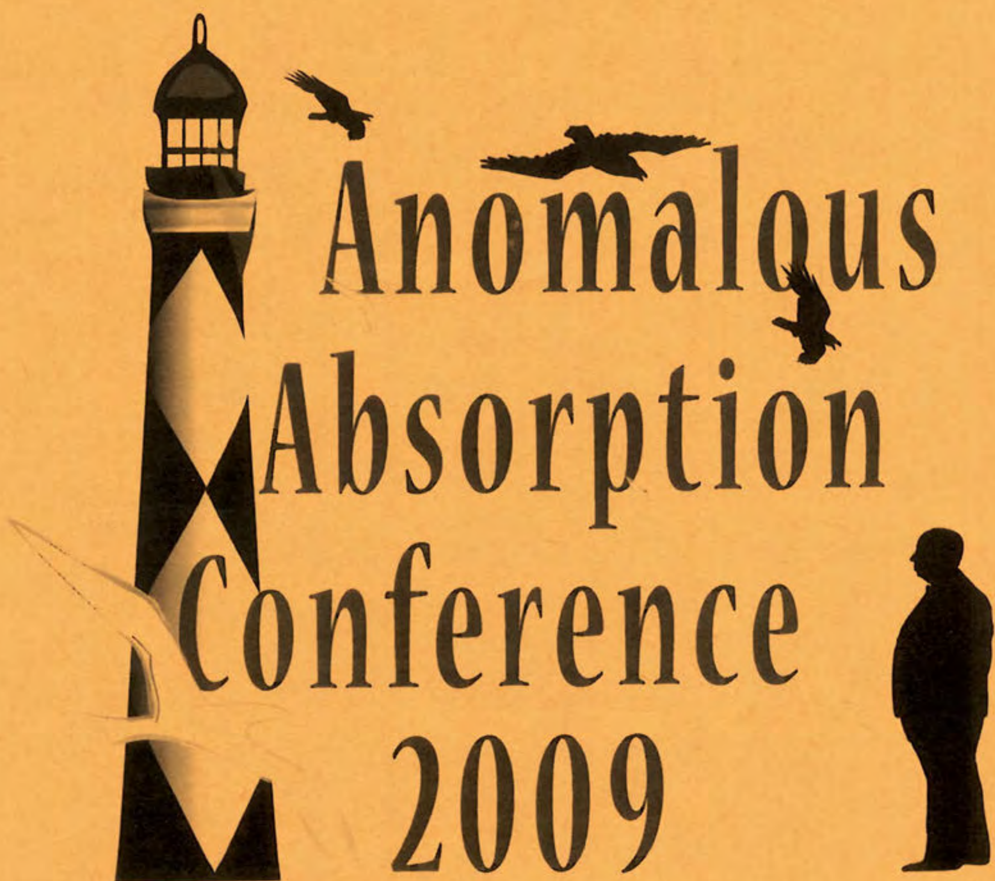
At these ultra-high intensities, we find that most of the energy transport is in a hot bulk and not in the super-hot tail of the electron distribution. Electrons in a relatively low energy range, below 3MeV, transport 90% of the heat flux through 50μm of 100n_c plasma to the target core. Hot electrons generated at the laser-plasma interface drive plasma turbulence in the background collisionless plasma heating it to MeV temperatures over picosecond time scales. Over the same time scale, Weibel instabilities generate large magnetic fields that confine the transverse spread of the heated plasma. The effect of these interactions with the background plasma is to lower the energy of the electrons entering the target core at the cost of energy used to heat the plasma, allowing for a higher absorption.

Our results show that the fraction of laser power that transits the dense plasma and is deposited into the core of the target increases with laser intensity. The fraction of laser energy deposited into the core after 2.5ps for a laser with intensity of $5x10^{19}$ W/cm^2 is 3.5%, this rises to 13% for an $8x10^{20}$W/cm^2 intensity laser.

The authors gratefully acknowledge the support by NSF under Grant PHY-0078508, and by DOE under Contract DE-FG03-NA0065 and DE-FG02-03ER54721 and DE-FG02-06ER54879, and the support of the HiPER project (EC FP7 project number 211737) in undertaking this work.

Invited Talk 3

Hohlraum Energetics Experimental Campaign on the National Ignition Facility



June 17, 2009

Wednesday

Chair – H. A. Baldis

✦ S. Glenzer ✦

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The Hohlraum Energetics experimental campaign on the National Ignition Facility*

S. H. Glenzer, N. Meezan, J. D. Moody, K. Widmann, D. H. Froula, L. Divol, R. L. Berger, P. Michel, J. Kline, D. H. Kalantar, S. Dixit, S. Lepape, E. Dewald, T. Doeppner, J. Ralph, D. Hinkel, D. Callahan, R. Wallace, E. Dzenitis, J. J. Kroll, J. S. Taylor, O. L. Landen, C. Haynam, J. Menapace, P. Wegner, E. I. Moses, L. J. Suter, B. MacGowan

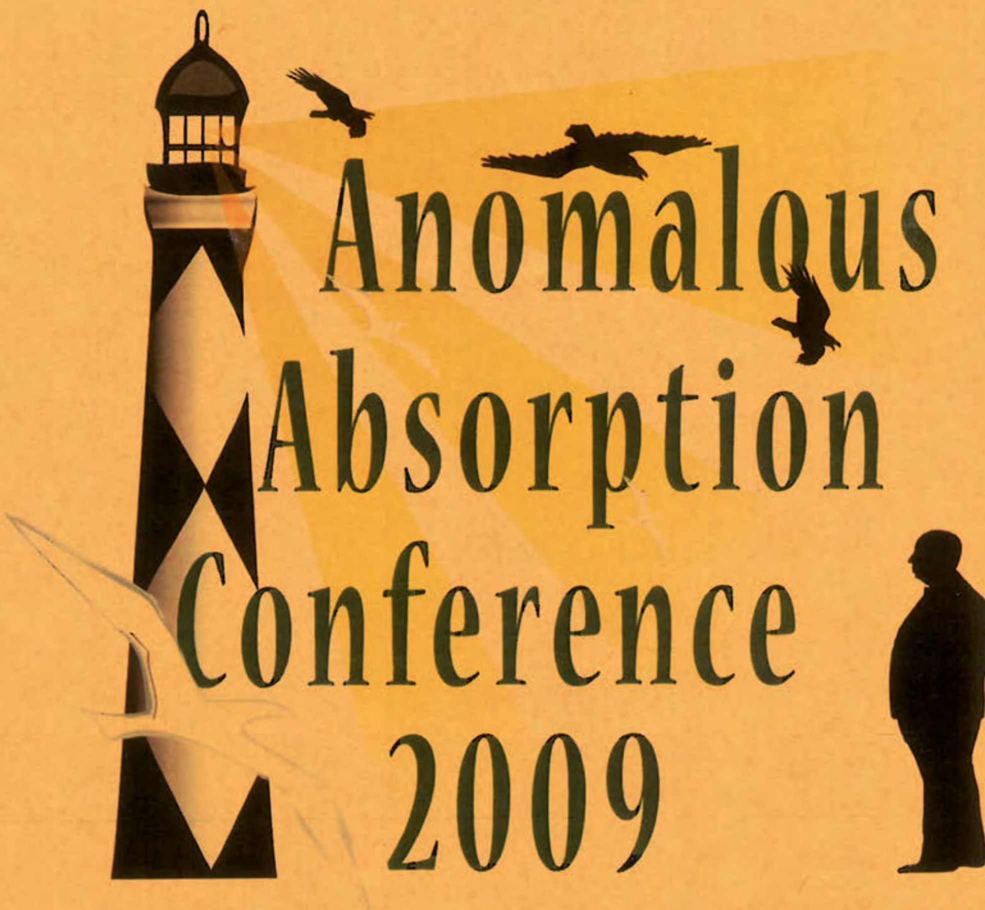
Lawrence Livermore National Laboratory, P.O. Box 808, Livermore, CA 94551, USA

We will review our plans for performing the hohlraum energetics experiments on the National Ignition Facility [1]. The experiments are designed to first activate target diagnostics and to demonstrate target experiments with cryogenic targets. In particular, a series of hohlraum and gas-filled target shots will be fielded to demonstrate performance of the absolutely calibrated soft x-ray spectrometer, Dante [2], the laser backscatter suite of diagnostics, i.e., the full aperture backscatter station (FABS) and Near Backscatter Imager (NBI) on two cones of the 48 quads of beams [3], and the absolutely calibrated hard x-ray bremsstrahlung detector, FFLEX. The campaign is designed to demonstrate laser beam intensity and laser conditioning to efficiently heat ignition hohlraums to radiation temperatures required to drive ignition capsules with laser energies in the range of 1-1.5 MJ. In this talk, we will discuss progress towards fielding this campaign on the National Ignition Facility and describe our approach for selecting the radiation temperature for ignition hohlraums.

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

ORAL SESSION 4

LPI III



June 18, 2009

Thursday

Chair – D. J. Strozzi

W. Seka ✦ J. F. Myatt ✦ D. Dubois ✦ H. Vu ✦ J. P. Palastro ✦ R. Kirkwood

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Experiments Indicate that the Two-Plasmon-Decay Instability is Insensitive to Laser Speckle

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The two-plasmon-decay (TPD) instability in direct-drive OMEGA experiments is seen in the half-integer harmonic and hard x-ray emission. Time-resolved $\omega/2$ and $3\omega/2$ spectra indicate that the linear theory for the absolute TPD instability reasonably predicts the TPD threshold. Inferred plasma-wave spectra do not agree with the predictions of the absolute instability. This is likely a consequence of the nonlinear evolution of this instability. The spectra indicate that the plasma waves have wave vectors extending to the Landau cutoff, $k_p\lambda_{De} \sim 0.25$, but not beyond. The maximum of the plasma-wave spectra appears to be located just below the Landau cutoff. The hard x-ray production caused by the TPD is sensitive only to the overlapped intensity in multibeam experiments and it is insensitive to hot spots (speckles). These observations are consistent with the plasma waves propagating transverse to the hot spots (speckles) rather than along them. Collisional or Landau damping lengths for typical ICF plasma parameters are two to three speckle widths for current plasma conditions. For average intensities in excess of $\sim 2 \times 10^{14}$ W/cm^2 the plasma-wave damping is offset by the TPD gain, permitting the plasma waves to sample essentially the entire beam cross section. These simple arguments agree well with observations and are supported by recent Zakharov simulations to be reported by J. F. Myatt, D. F. DuBois, D. A. Russell, H. X. Vu, A. V. Maximov, and R. W. Short.
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Extended Zakharov Predictions of Anomalous Absorption in Inhomogeneous ICF Relevant Plasma Due to the TwoPlasmonDecay Instability

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The results of twodimensional extended Zakharov calculations[1] of saturated twoplasmondecay spectra and absorption will be presented in inhomogeneous longscalelength plasma; the plasma parameters motivated by OMEGAscale Directdrive designs. Particular attention is paid to the effects of multiple crossing beams, and the possibility of driving a common "shared" plasma wave.[2] The effect on absorption of beam intensity, beam crossing angle, and ionacoustic wave damping rate are examined and possible preheat mitigation strategies discussed. Estimates of preheat are compared with *LILAC* predictions of target performance and OMEGA experimental data. The effect upon the "shape" of the saturated spectrum of plasma waves of overlapping beams is compared to hotelectron bremsstrahlung measurements in planar foil targets and the likely directionality of hot electrons (on which preheat is dependent) are inferred.[3]

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1. D. F. DuBois, D. A. Russell, and H. A. Rose, Phys. Rev. Lett. 74, 3983 (1995); D. A. Russell and D. F. DuBois, Phys. Rev. Lett. 86, 428 (2001).
2. W. Seka *et al.*, "TwoPlasmonDecay Instability in DirectDrive Inertial Confinement Fusion Experiments," to be published in Physics of Plasmas.
3. J. F. Myatt *et al.*, Bull. Am. Phys. Soc. 53, 168 (2008).

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1/2 w_0 Emission from the Nonlinear Currents Generated by the Two Plasmon Decay Instability

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Light emission at 1/2 and 3/2 times the laser frequency has long been a diagnostic for the laser excitation of the two plasmon decay (TPD) instability [1]. Assuming that the power emitted at these frequencies is small compared to the power in the plasma waves directly excited in the nonlinear stage of the instability, the radiated power can be calculated by post processing in RPIC and Zakharov simulations. Current envelopes at the frequencies1/2 w_0 and 3/2 w_0 can be calculated which determine the radiated frequency spectra [2]. The 3/2 w_0 current is just that expected from Thomson upscatter of the laser from the Langmuir wave (LW) fluctuations and is shown in the following paper [Russell *et al.*] to be dominated by the secondary LWs resulting from the Langmuir decay instability (LDI) of the primary LWs from TPD [3]. The current amplitude at 1/2 w_0 is more complex and consists of a Thomson downscatter term, a term resulting from linear mode conversion of LWs on the density gradient, and a term describing the nonlinear conversion of LWs into light waves (near 1/2 w_0) by scattering on ion acoustic waves (IAWs). The ion acoustic waves are produced by the LDI saturation. This nonlinear mode conversion process is the dominant contribution to the 1/2 w_0 current in some cases. The frequency spectrum of the light emitted near 1/2 w_0 has two peaks, as observed, with a frequency separation on the IAW scale. The 1/2 w_0 emission is complicated since this light is emitted near its reflection point. Emission very near one quarter of the critical density is ruled out since ponderomotive density modification moves the turbulent region to lower densities.

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[1]See e.g.Seka et al, earlier paper in this conference
[2]D.F.DuBois, D.A.Russell,and H.A. Rose , PRL 74, 3983 (1995)
[3]D.A.Russell, and D.F.DuBois, PRL 86, 428 (2001)

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Hot Electron Production from the TwoPlasmon Decay Instability*

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The reduced-description particle-in-cell (RPIC) code was recently adapted to include the two-plasmon decay instability (TPD), and results indicate that for some parameter regimes, hot electrons attain a modest temperature of a few times the background electron temperature. Simulations of a single laser beam and of two crossed laser beams, in which TPDs share a common Langmuir wave, are presented at various background electron plasma temperatures. These simulations are performed both in homogeneous plasmas and in plasmas with a linear gradient in the background density. Comparisons with the extended Zakharov simulations show remarkably similar spectral features.

*Research supported by contract # DEFC5208NA28302 from LLE.

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KINETIC DISPERSION OF LANGMUIR WAVES*

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We have derived a fully kinetic, three-dimensional dispersion relation for Langmuir waves, which reproduces the non-linear dispersion relations for the Langmuir decay instability (LDI), the Langmuir modulational instability (LMI), and ponderomotive Langmuir Filamentation (LF), and includes ponderomotive frequency shifts. We explore, in detail, which of these processes dominate in different regions of parameter space. The kinetic dispersion is also compared to the standard fluid dispersion found with an equation of state (EOS) closure. The EOS closure fails to capture the intricacies of the non-linear pressure when high frequency electron plasma waves (EPWs) couple to low frequency ion acoustic waves (IAWs). In particular, discrepancies emerge in the $k\lambda_d$ scalings in the coupling and non-linear frequency shifts associated with LDI. As a result, the kinetic dispersion for LDI results in instability thresholds that can be in excess of twice those predicted by the fluid theory. Even for small $k\lambda_d$, discrepancies can emerge in the non-linear coupling for LMI and LF: the fluid dispersion relation can erroneously predict instability in particular regions of parameters space.

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Amplification of light by Langmuir waves in a hot, strongly damped plasma and its relevance to ignition and pulse compression*

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N. J. Fisch, V. M. Malkin, E. O. Valeo, Princeton University
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We are studying plasma amplification of high intensity light by ns duration laser pulses as is relevant to the amplification of SRS backscatter in ignition experiments and also may be capable of increasing the power in beams with a duration of ~ 1 ps or less. The amplification process is compatible with a high temperature, low density, plasma that will coexist with >100 kJ of total pump energy, and will damp the waves strongly. In one potential application, this plasma amplification process can be used to dramatically increase the beam power and intensity by interaction of a ns pump beam with a ~ ps duration, higher focal quality, seed. The plasma conditions and seed pulse duration are also relevant to studying the non-linear physics of the low gain amplification of SRS backscatter produced by the crossing beams in ignition targets. In particular the seed pulse duration allows the study of the non-linear response of the Langmuir wave on the short time scale of the electron kinetic saturation expected in ignition experiments at higher kl_{Debye}, while avoiding the secondary ion wave decays that could affect SRS on the ns time scale at this kl_{Debye}. Experiments in a 3 mm long plasma, created by a 200 J, 1ns pump beam, and intersected by a counter propagating, frequency shifted seed beam (<~ 10 mJ, 1 – 3.5 ps) show the seed is amplified ~ 10x by SRS with $kl_{Debye} \sim 0.4$. Further when the f/10 pump beam is below the filamentation threshold some of its energy is transferred to the f/25 seed and maintain the seed f/number. Data will be presented showing that the scaling of the amplified seed energy with input seed energy and pump intensity in this regime is consistent with wave saturation by electron kinetic nonlinearity under these conditions. The relevance to ignition experiments and potential applications to the production of high intensity, short pulse beams will also be discussed.

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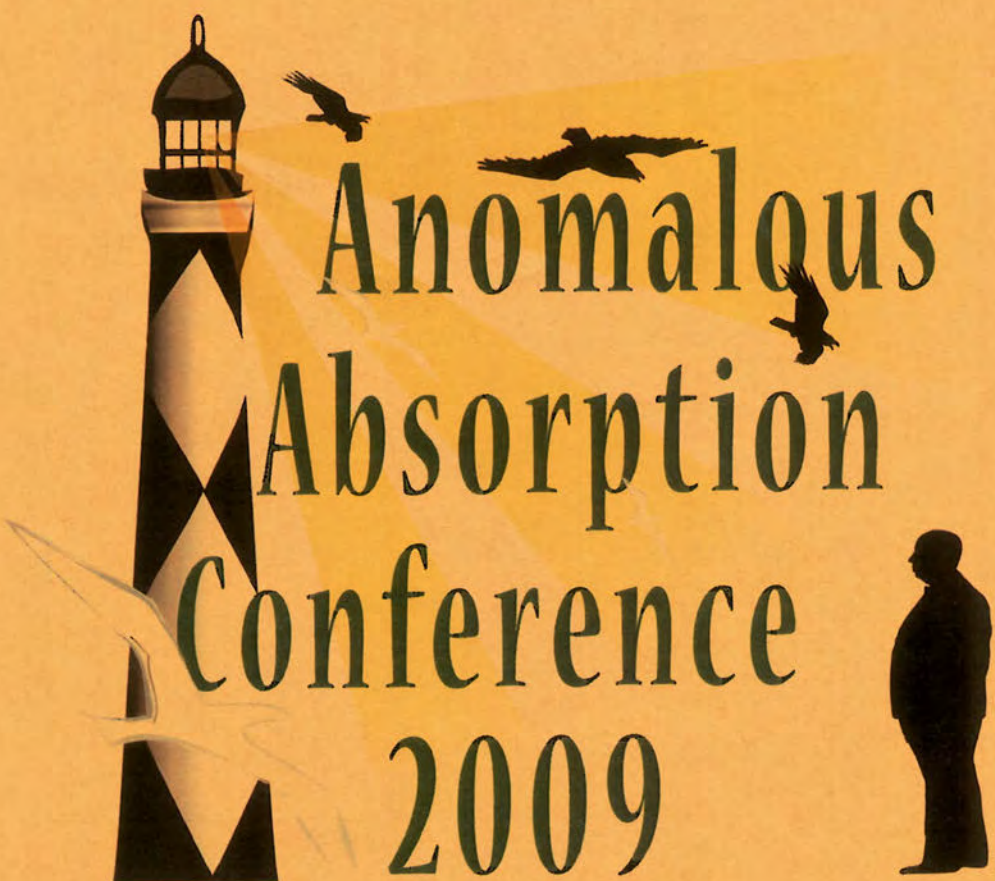
ORAL SESSION 5

LPI IV



June 19, 2009

Friday
Chair – A. B. Langdon

D. E. Hinkel ✦ P. Michel ✦ R. L. Berger ✦ L. Divol ✦ D. J. Strozzi ✦ L. Yin ✦ P.-E. Masson-Laborde

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Laser-plasma interactions in emulators of NIF ignition targets*

D. E. Hinkel, A. B. Langdon, S. H. Langer, C. H. Still, and E. A. Williams
Lawrence Livermore National Laboratory

The first energetics experiments at the National Ignition Facility will utilize sub-scale targets that emulate the plasma conditions of full-scale ignition designs.[1] These targets have lower laser intensity and are shorter in length, but by utilizing smaller spots and increasing the power of an interaction beam we can assess laser-plasma interactions (LPI) at ignition scale.

To this end we have performed a suite of pF3D simulations of whole and near-whole beam propagation simulation of realistic laser beams from the target entrance hole to the wall. Such simulations include both axial and transverse gradients in the plasma profiles, and are massively parallel, requiring in excess of thousands of cpus.

We present simulations of emulators, and compare results to pF3D simulations of ignition designs. We analyze reflectivity and transmission, assess generated hot electrons, predict backscatter spectra and near-backscatter images, and show the role of re-absorption of the backscattered light on laser energy deposition.

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Collective amplification of stimulated Raman and Brillouin scattering by multiple laser beams in ignition experiments*

Pierre Michel, Laurent Divol, Nathan Meezan, Robert Kirkwood, Ed Williams, David Strozzi, Debbie Callahan, Siegfried Glenzer and Larry Suter
Lawrence Livermore National Laboratory

Laser-plasma instability studies on the most recent ignition target designs have shown that the reflectivity levels of individual laser beams should remain small (a few percents at most) [1]. However we will show in this talk that the backscattered light could be collectively amplified on its way out of the hohlraum by all the laser beams crossing at the laser entrance hole (LEH). The process is similar to a two-stage Raman or Brillouin amplifier, with a pre-amplifier inside the target generating the seed, which gets subsequently amplified by a second amplifier stage at the LEH. The amplification by each single laser beam is typically small, with linear gain exponents much smaller than unity over long distances (about a millimeter). However the contribution of all laser beams crossing at the LEH can lead to amplification of the seed by up to several orders of magnitudes. We will show how a careful choice of target design and material composition can mitigate this problem by reducing the amplification gain and detuning the pre-and post- amplifiers spectral domains.
[1]: D. Hinkel et al., Phy. Plasmas 15, 056314 (2008)

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What do OMEGA experiments results say about the suppression of Stimulated Brillouin Scattering from NIF hohlraums with gold-boron layers?*

R. L. Berger, L. Divol, D. Froula, S. H Glenzer, R. London, N. Meezan, P. Neumayer, and L. J. Suter

Lawrence Livermore National Laboratory

The long laser pulse length required to achieve ignition on NIF can create long scalelength, hot, high-Z plasma inside the hohlraum from which stimulated Brillouin scatter is predicted to be 20-40%. We also predict that adding ~40% Boron or other low Z elements to a thin layer of the high-Z wall reduces the predicted SBS to less than a percent. In the past few years, a number of experiments at the OMEGA laser facility have tested elements of the physics of SBS in gold-boron and the modeling tools. The damping rates for pure gold plasma and plasmas with various gold-boron mixtures can be duplicated with mixtures of CO2 and hydrocarbon gasses. By combining the rad-hydro code HYDRA to compute bulk plasma parameters and the paraxial-wave-solver pF3d to compute backscatter, levels of stimulated Brillouin backscatter that agree with the measurements have been predicted in advance of the experiments. Although the SBS increases with the calculated average gain as expected, closer examination shows that, for the same gain, plasmas with very weakly damped ion acoustic waves Brillouin scatter light more strongly than plasmas with more strongly damped ion acoustic waves. The pF3d simulations also show that behavior. We explore theoretical explanations for this behavior and the implications for our NIF designs.

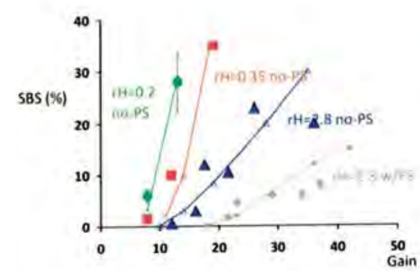

Figure. The symbols with error bars represent the measured stimulated Brillouin backscatter measured at OMEGA in hohlraum experiments. The lines are predictions of the level of backscatter. The ion acoustic wave damping increases with the fraction of hydrogen, rH. The sensitivity of the SBS to ion acoustic wave damping is clear in both the data and the simulations.

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Speckles effect in stimulated backscatter*

L. Divol, E.A. Williams, P. Michel , D. Froula and R. L. Berger

Lawrence Livermore National Laboratory

We will discuss the role of laser speckles in spatially smoothed laser beam when studying stimulated backscatter. Through full 3D numerical results and various analytical approximations, we will discuss the impact of plasma length, numerical aperture (i.e. speckle length), finite spot size, backscatter wavelength and polarization smoothing on backscatter.

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Role of Electron Trapping in SRS on NIF Ignition Targets

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Nonlinearity in Langmuir waves due to the trapping of resonant electrons, such as the reduction in Landau damping, frequency downshift, and trapped-particle modulational instability, have been studied for some time. In this talk, we present a simple threshold criterion for the onset of trapping effects. Namely, the number of bounce orbits completed by resonant electrons before being detrapped by various loss mechanisms, called the bounce number, must exceed roughly unity. We find that, for regions of NIF ignitions targets where stimulated Raman scattering (SRS) is expected to grow, geometric sideloss out of laser speckles provides a significantly higher threshold than Coulomb collisions. By post-processing SRS simulations with the enveloped, paraxial code pF3D, the fraction of pump laser exposed to bounce numbers above one can be substantial. Different designs will be compared for their relative risk to trapping nonlinearity.

Reduced models of trapping physics are needed to go beyond this simple figure of merit. We have incorporated some such models into pF3D, as well as compared them to 1D Vlasov simulations. The effects of trapping on SRS properties like reflectivity, temporal evolution, and scattered light spectrum, using these various descriptions, will be compared.

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Saturation of backward stimulated Raman scattering of laser in trapping regime*

L. Yin, B. J. Albright, H. A. Rose, K. J. Bowers♦, B. Bergen, S. M. Finnegan, J. L. Kline, D. S. Montgomery, and J. C. Fernández

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A suite of three-dimensional (3D) VPIC [1] particle-in-cell simulations of backward stimulated Raman scattering (SRS) in ICF hohlraum and Trident plasma have been performed on the heterogeneous multi-core supercomputer, Roadrunner, presently the world's most powerful supercomputer. These calculations reveal the complex nonlinear behavior of SRS and point to a new era of "at scale" 3D modeling of SRS in solitary and multi- laser speckles. The physics governing nonlinear saturation of SRS in a laser speckle in 3D is consistent with that of prior 2D studies [2], but with important differences arising from enhanced diffraction and side loss in 3D compared with 2D. In addition to wavefront bowing of electron plasma waves (EPW) due to trapped electron nonlinear frequency shift and amplitude-dependent damping, we find for the first time that EPW self-focusing, evolved from trapped particle modulational instability [3], also exhibits loss of angular coherence by formation of a filament necklace, a process not available in 2D. These processes in higher dimensions increase the side-loss rate of trapped electrons, increase wave damping, decrease source coherence for backscattered light, and fundamentally limit how much backscatter can occur from a laser speckle. For both SRS onset and saturation, the nonlinear trapping induced physics is not captured in linear gain modeling of SRS, as previously observed in Trident experiments [4]. By employing a binary collision model [5] in VPIC to sample the Fokker-Planck collision operator, the influence of collision on SRS saturation is also examined.

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Self-focusing induced Reduction of Stimulated Brillouin Scattering of Intense Laser Beams interacting with Expanding Plasmas

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The mechanisms explaining the low level of Stimulated Brillouin scattering (SBS) observed in laser-plasma experiments with monospeckle and smoothed laser beams are studied by means of numerical simulations. For the regime where the power of singles speckles is well above the self-focusing critical power, simulations show time-averaged reflectivities of the order of only a few percent, in very good agreement with experiments carried out at the LULI facility. Because of self-focusing and the filament resonant instability, SBS takes only place in self-focused hot spots located in the low-density front part of the expanding plasma. The shortened hot spot sizes and the plasma profile modifications dramatically reduce SBS. We present a reduced model explaining the gain reduction and correspondingly the low SBS level.