36th Annual Anomalous Absorption Conference

Jackson Hole, Wyoming
June 4-9, 2006

Organizing Committee
David S. Montgomery
John L. Kline
Bedros B. Afeyan

Los Alamos NATIONAL LABORATORY EST 1943

Polymath Research Inc.

36^{th} Annual
Anomalous Absorption Conference

Snow King Resort
Jackson Hole, Wyoming
June 4-9, 2006

Conference Organizers
David S. Montgomery, Los Alamos National Laboratory
John L. Kline, Los Alamos National Laboratory
Bedros B. Afeyan, Polymath Research, Inc.

Support Staff
Nancy Riebe, Peggy Vigil, Lucy Maestas
Nolan Carter, Jim Douglass
Los Alamos National Laboratory

Agenda for the 36th Annual Anomalous Absorption Conference
Snow King Lodge, Jackson Hole, Wyoming
June 4th – June 9th, 2006

Sunday, June 4th

Registration	6:00 – 8:00 PM			TETON & MEZZANINE
Reception	6:00 – 8:00 PM			

Monday, June 5th

BREAKFAST	7:00 – 8:45 AM			ATRIUM RESTAURANT
Registration	7:45 – 8:45 AM			LODGE ROOM FOYER
Welcome	8:45 – 9:00 AM	Conference Organizing Committee		LODGE ROOM
Oral Session		Session Chair: Bedros Afeyan, *Polymath Research*		LODGE ROOM
Invited Talk	9:00 – 10:00 AM	D. Montgomery	Laser-Plasma Instability Experiments: From Understanding to Mitigation	
Contributed	10:00 – 10:20	L. Yin	PIC Simulations of Nonlinear Backward Stimulated Raman Scattering in the Kinetic Regime	
	10:20 – 10:40	H. Rose	Stimulated Raman Scatter Convective Threshold in a Speckled Laser Beam	
Coffee Break	10:40 – 11:00			
Contributed	11:00 – 11:20	B. Afeyan	Where in the (ω-k) Plane Can KEEN Waves Live?	
	11:20 – 11:40	Th. Fouquet	Nonlinear Evolution of SRS Coupled with LDI in a Multidimensional Inhomogeneous Plasma	
	11:40 – 12:00	D. Pesme	One-dimensional PIC Simulations of Stimulated Raman Scattering: Comparison with Fluid Type Modeling	
	12:00 – 12:20	L. Divol	On the Effect of SSD on Backscattering Instabilities in the Absence of Filamentation/Forward SBS	
LUNCH	12:30 – 1:30 PM			LODGE ROOM DECK
Focus Group	1:30 – 3:00 PM	Long-pulse LPI Discussions		LODGE ROOM
DINNER	6:00 – 7:00 PM			TETON ROOM
Evening Invited		Session Chair: Stefan Hüller, *Ecole Polytechnique*		LODGE ROOM
Invited Talk	7:00 – 8:00 PM	C. Rousseaux	Experimental Studies of Parametric Instabilities Using Short Pulse Lasers From High-Intensity Propagation Experiments to Sub-ps Thomson Scattering Diagnostic Experiments	

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Monday, June 5th

Poster Session 8:00 – 11:00 PM Session Chair: Stefan Hüller, *Ecole Polytechnique* LODGE ROOM

Mo01	B. Albright	One-Dimensional Theory of Laser Acceleration of Light Ion Beams from the Interaction of Ultrahigh Intensity Lasers with Layered Target
Mo02	J. Tonge	PIC Simulation of Fast Ignition Targets with OSIRIS
Mo03	R. Mason	Implicit Scoping Calculations for Fast Ignition
Mo04	J. Oh	Nike Experiments on Shock Propagation with a Short Spike Prepulse
Mo05	G. Magelssen	Ignition Design NIF and Reemission Ball Diagnostic for Early Time Symmetry Measurements
Mo06	M. Karasik	Laser Imprint Suppression with High-Z Layers at High Foot Intensities
Mo07	S. Hughes	Development of the Electron Transport Model in Radiation-Hydrodynamic Codes
Mo08	B. Afeyan	Exploiting Sparsity and Morphological Diversity to Characterize the Uniformity of Spherical Shells in ICF Targets and their Radiation Driven Implosions
Mo09	M. Casanova	Revisiting the Parametric Instabilities in an Inhomogeneous Plasma
Mo10	Th. Fouquet	Extensive Simulations Concerning the Nonlinear Evolution of SRS Coupled with the Langmuir Decay Instability in a Multidimensional Inhomogeneous Plasma
Mo11	F. Tsung	Particle in Cell Simulations of the Two Plasmon Decay Instability for Plane Waves in Inhomogeneous Plasmas
Mo12	D. Froula	3ω Laser Beam Propagation in High Temperatures and Long-Scale Length Plasmas

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Tuesday, June 6th

BREAKFAST	7:00 – 9:00 AM			ATRIUM RESTAURANT
Registration	7:45 – 8:45 AM			LODGE ROOM FOYER
Oral Session		Session Chair: Juan Fernández, *Los Alamos National Laboratory*		LODGE ROOM
Invited Talk	9:00 – 10:00 AM	M. Tabak	Issues in Fast Ignition	
Contributed	10:00 – 10:20	J. Myatt	Laboratory Demonstration of e^+e^- Pair-Plasma Production on OMEGA EP	
	10:20 – 10:40	Y. Ping	Absorption and Energy Partition of Short Laser Pulses in the Relativistic Regime	
Coffee Break	10:40 – 11:00			
Contributed	11:00 – 11:20	R. Kirkwood	Observation of Amplification of a 1ps Pulse by SRS of a 1ns Pulse in a Plasma with Conditions Relevant to Pulse Compression	
	11:20 – 11:40	R. Mason	Cone Targets Revisited	
	11:40 – 12:00	R. Short	Filamentation of Fast-Ignition Electron Transport in Plasmas: Spatial Growth and Absolute Modes	
	12:00 – 12:20	A. Maximov	Transport Near the Critical Density Surface in Direct-Drive ICF Plasmas	
LUNCH	12:30 – 1:30 PM			LODGE ROOM DECK
Focus Group	1:30 – 3:00 PM	Short Pulse & Fast Ignition Discussions		LODGE ROOM
DINNER	6:00 – 7:00 PM			TETON ROOM
Evening Invited		Session Chair: John Kline, *Los Alamos National Laboratory*		LODGE ROOM
Invited Talk	7:00 – 8:00 PM	C. Geddes	Wakefield Accelerators for Ultrafast Particle and Radiation Sources Using Short-Pulse Lasers	
BUSINESS	8:00 – 8:15 PM	BUSINESS MEETING, Conference Organizers, 2006 & 2007		LODGE ROOM

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Tuesday, June 6th

Poster Session 8:15 – 11:00 PM Session Chair: John Kline, *Los Alamos National Laboratory* LODGE ROOM

Tu01	W. Mori	Prospects for 100+ GeV Laser Wakefield Accelerator Stages
Tu02	U. Schramm	Design study for a table-top VUV/X-ray FEL driven by laser accelerated electron beams
Tu03	J. Cobble	Gold Influx in Laser-Driven Hohlraums
Tu04	G. Huser	Planar Rayleigh-Taylor and Feedthrough Experiments with CHGe on Omega
Tu05	D. Colombant	Effects of a Prepulse on the Performance and Stability of Direct-Drive Laser Fusion Targets
Tu06	N. Metzler	Stabilization effects of density graded foams on perturbations due to target imperfections at the outer surface
Tu07	H. Rose	Langmuir Wave Decay Instability for Large $k\lambda_D$
Tu08	D. Strozzi	Parametric Studies of Kinetically-Enhanced Raman Backscatter and Electron Acoustic Thomas Scattering
Tu09	B. Winjum	Nonlinear Effects on the Saturation of Stimulated Raman Scattering
Tu10	J. Kline	Investigation of Stimulated Raman Scattering Using a Short-Pulse Single-Hot-Spot at the Trident Laser Facility
Tu11	J. Fahlen	Cavity Formation and Collapse in Stimulated Brillouin Scattering
Tu12	B. Cohen	Kinetic-Ion Simulations and Reduced Models for Stimulated Brillouin Backscattering

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Wednesday, June 7th

BREAKFAST	7:00 – 9:00 AM			ATRIUM RESTAURANT
Registration	7:45 – 8:45 AM			LODGE ROOM FOYER
Oral Session		Session Chair: Stephen Craxton, *Univ. Rochester LLE*		LODGE ROOM
Invited Talk	9:00 – 10:00 AM	M. Marinak	New Capabilities for Simulations of Radiation Hydrodynamics and Challenges for the Future	
Contributed	10:00 – 10:20	S. Zalesak	Thoughts on the Modeling of Fluid Instabilities in Inertial Confinement Fusion Hydrodynamics Codes	
	10:20 – 10:40	P. Amendt	Prospects for Achieving Double-Shell Ignition on the NIF using Vacuum Hohlraums	
Coffee Break	10:40 – 11:00			
Contributed	11:00 – 11:20	A. Schmitt	Performance and Stability of Sub-MJ Direct-Drive Pellets	
	11:20 – 11:40	S. Craxton	An Update on Polar-Direct-Drive Experiments on Omega	
	11:40 – 12:00	R. Petrasso	A Monoenergetic Proton Backlighter for Measuring E and B Fields and for Radiographing Implosions and HED Plasmas	
	12:00 – 12:20	C.K. Li	Measuring E and B Fields in Laser-Produced Plasmas Through Monoenergetic Proton Radiography	
LUNCH	12:30 – 1:30 PM			LODGE ROOM DECK
Focus Group	1:30 – 3:00 PM	Hydrodynamic Simulations and Expeiments Discussions		LODGE ROOM
RECEPTION	5:45 – 6:30 PM			TETON ROOM & MEZZANINE
LOAD BUS	6:30 – 7:00 PM	TRANSPORTATION TO BAR-J RANCH		SNOW KING ENTRANCE
BANQUET	7:00 – 10:00 PM	Chair, David Montgomery, *Los Alamos National Laboratory*		BAR-J RANCH
COWBOY SINGING		The Bar-J Wranglers, *Bar-J Ranch, Jackson Hole WY*		BAR-J RANCH
LOAD BUS	10:00 – 10:30 PM	TRANSPORTATION TO SNOW KING LODGE		

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Thursday, June 8th

BREAKFAST	7:00 – 9:00 AM			ATRIUM RESTAURANT
Oral Session		Session Chair: Laurent Divol, *Lawrence Livermore National Laboratory*		LODGE ROOM
Invited Talk	9:00 – 10:00 AM	N. Meezan	Progress and Challenges in Hydrodynamics Simulations for Laser-Plasma Interaction Predictive Capability	
Contributed	10:00 – 10:20	S. Hüller	Modeling Parametric Scattering Instabilities in Large-scale Expanding Plasmas	
	10:20 – 10:40	P. Loiseau	Light Spreading Induced by Stimulated Brillouin Scattering in an Inhomogeneous Flowing Plasma	
Coffee Break	10:40 – 11:00			
Contributed	11:00 – 11:20	D. Strozzi	Vlasov Stimulations of Kinetically-Enhanced Raman Backscatter, and Electron Acoustic Thomson Scatter	
	11:20 – 11:40	D. DuBois	Implications of the Trapping-Inflation Scenario for SRS	
	11:40 – 12:00	B. Bezzerides	RPIC Simulations as Experiments: Developing a Comprehensive Model of Raman Inflation	
	12:00 – 12:20	H.X. Vu	A Threshold for Superlinear Enhancement of Stimulated Raman Scattering by Electron Trapping	
LUNCH	12:30 – 1:30 PM			LODGE ROOM DECK
DINNER	6:00 – 7:00 PM			TETON ROOM
Evening Invited		Session Chair: Frank Tsung, *University of California, Los Angeles*		LODGE ROOM
Invited Talk	7:00 – 8:00 PM	B. Albright	Kinetic Plasma Simulation Tools and Outlook	

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Thursday, June 8th

Poster Session 8:00 – 11:00 PM Session Chair: Frank Tsung, *University of California, Los Angeles* LODGE ROOM

Th01	T.W. Johnston	Transverse Field Compression and Harmonics in Light from P-Polarized Laser Pulses Obliquely Incident on Thick Overdense Plasmas with Steep Gradients
Th02	W. Manheimer	The Krook Collision Model as a Template for Calculating Electron Thermal Flux in Laser Produced Plasmas
Th03	S.R. Goldman	Simulations of Gas-filled Hohlraums for LPI Experiments at Omega
Th04	J. Cooley	Evaluation of Effects of Bonding Joint in Machined Capsules on Ignition at the NIF
Th05	L. Suter	Outer Beam Focal Spots for the 2009 and 2010 NIF Ignition Experiments
Th06	N. Delamater	Calculations of Foam Filled NIF Ignition Hohlraums at 1 MJ Laser Energy
Th07	J. Weaver	Experimental Studies of Laser Plasma Instabilities at the Nike Laser
Th08	J. Kline	Investigation of High-Z dopants to Mitigate Stimulated Raman Scattering in Gas-Filled Hohlraums
Th09	M. Grech	Experimental Investigation of the Plasma Induced Laser Beam Smoothing on the ALISE Laser Facility
Th10	W. Kruer	Laser Plasma Instability Reduction by Coherence Disruption and Other Techniques-II
Th11	E. Dodd	Laser-Plasma Instabilities in NIF Target Design
Th12	J. Fahlen	Driven Electron Plasma Waves Relevant to Raman Scattering

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Friday, June 9th

BREAKFAST	7:00 – 8:30 AM			ATRIUM RESTAURANT
Oral Session		Session Chair: Denise Hinkel, *Lawrence Livermore National Laboratory*		LODGE ROOM
Invited Talk	8:30 – 9:30 AM	M. Stevenson	Proton Backlit Observations of Filamentation in Homogeneous Plasmas	
Contributed*	9:30 – 9:50	M. Grech	Modification of Laser Beam Coherence Properties During the Propagation Through Underdense Plasmas	
	9:50 – 10:10	S. Prisbrey	Design of a Potential Single Quad Intensity Scaling Experiment for LIL	
	10:10 – 10:30	D. Hinkel	Laser-Plasma Interactions in 2010 Ignition Targets	
	10:30 – 10:50	W. Seka	Laser Absorption in Spherical Target Experiments on OMEGA	
	10:50 – 11:10	E. Williams	Crossed Beam Power Transfer in NIF ignition targets and the two-color option	
	11:10 – 11:30	S. Langer	Simulations of Recent Omega Fill Tube Experiments	
ADJOURN	11:30 – 11:35	Conference Organizers Adjourn 2006 Anomalous Absorption		
LUNCH	11:35 – 12:30 PM	Box Lunches		LODGE ROOM DECK

2006 Anomalous Absorption
Conference Organizers

Chair: David S. Montgomery, *Los Alamos National Laboratory*
Co-Chair: John L. Kline, *Los Alamos National Laboratory*
Co-Chair: Bedros B. Afeyan, *Polymath Reseach Inc.*

Admin: Nancy Riebe, Peggy Vigil, Lucy Maestas,
Nolan Carter, Jim Douglass

* in the interest of adjourning earlier due to flight availability, session will start earlier and have no coffee break, but coffee & snack available on the side

Monday, June 5, 2006

8:45 -	9:00 AM	Welcome/Opening Remarks Conference Organizing Committee
9:00 -	10:40 AM	Oral Session 1 Session Chair: B. Afeyan
10:40 -	11:00 AM	Coffee Break
11:00 -	12:20 PM	Oral Session 2 Session Chair: B. Afeyan
12:30 -	1:30 PM	Lunch
1:30 -	3:00 PM	Focus Group Long-Pulse LPI Discussions
7:00 -	8:00 PM	Invited Talk – C. Rousseaux Session Chair: S. Hüller
8:00 -	11:00 PM	Poster Session

Morning Invited Talk 1

Speaker: D. Montgomery
9:00 am – 10:00 am

Session Chair: Bedros Afeyan,
Polymath Research

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Laser-Plasma Instability Experiments: From Understanding to Mitigation

David S. Montgomery
Los Alamos National Laboratory
Los Alamos, MS 545

In recent years, our understanding of the growth and nonlinear behavior of laser-plasma instabilities has blossomed, and many theoretically predicted phenomena have now been observed in laboratory experiments. Examples include observation of the effects of particle trapping for both Langmuir waves and ion acoustic waves, multiple wave-wave interactions of these plasma waves, the effects due to the interaction of multiple laser beams compared to single laser beams, as well as the observation of new nonlinear structures. Much progress has also been made in comparing the results of nearly ideal experimental configurations to quantitative *ab initio* models. Despite this success, a quantitative predictive capability for more complex experimental configurations, such as for ignition target designs, is still being developed. As we approach the challenges that lie ahead for achieving ignition, the potential risks created by plasma instabilities will require well thought out plans to mitigate their effect. We will discuss some specific experimental strategies for mitigating the risk of laser-plasma instabilities, and will describe a simple theoretical framework for designing such experiments. Some of the challenges and issues of adopting these strategies will be discussed.

LA-UR-06-3492

Oral Session 1

10:00 am – 10:40 am

Session Chair: Bedros Afeyan,
Polymath Research

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PIC Simulations of Nonlinear Backward Stimulated Raman Scattering in the Kinetic Regime*

L. Yin, W. Daughton, B. J. Albright, K. J. Bowers, D. S. Montgomery, J. L. Kline, and J. C. Fernandez,
Los Alamos National Laboratory, Los Alamos, NM 87545, USA

The nonlinear backward stimulated Raman scattering (SRS) of a laser is examined with linear theory and particle-in-cell (PIC) simulations in one and two dimensions. The study is performed under conditions resembling that of the Trident single hot-spot experiments at LANL [1,2] to model the SRS reflectivity scaling with laser intensity and $k\lambda_D$ (k is the Langmuir wave-number and λ_D is the plasma Debye length). It is shown that the electron beam acoustic modes (BAM) evolve from Langmuir waves as electron trapping modifies the distribution to a non-Maxwellian form that exhibits a beam component. The intersection of the Stokes root with BAM determines the matching conditions for BSRS at a nonlinear stage. As the frequency of the unstable Stokes mode decreases with increasing wavenumber, the damping rate and the phase velocity of BAM decrease with the phase velocity of the Stokes mode, providing a self-consistently evolving plasma linear response that favors continuation of the nonlinear frequency shift [3]. Both the reflectivity scaling with laser intensity and the spectral features from simulations are discussed and are consistent with Trident experiments. The details of the wave-particle interaction region in the electron velocity distribution determine the growth/damping rate of these electrostatic modes and the nonlinear frequency shift. In modeling this behavior, the use of sufficiently large numbers of particles in the simulations is crucial.

[1] D. S. Montgomery, et al., Phys. Plasmas, 9, 2311 (2002).
[2] J. L. Kline, et al., "Different $k\lambda_D$ regimes for non-linear effects on Langmuir waves", Phys. Plasmas, in press (2005).
[3] L. Yin, et al., Phys. Rev. E. 73, 025401(R) (2006).

*This work was performed under the auspices of the U.S. Department of Energy (DOE) by the University of California Los Alamos National Laboratory (LANL) under contract No. W-7405-Eng-36.

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Stimulated Raman Scatter Convective Threshold in a Speckled Laser Beam

Harvey A. Rose
Los Alamos National Laboratory

Stimulated Raman scatter from a speckled laser beam, in the strongly damped regime, may exhibit a divergent mean gain, $\langle G \rangle$, and reflectivity, $\langle R \rangle = \langle G \rangle R_0$, according to linear theory as the average laser intensity, $\langle I \rangle$, approaches a critical value, I_c. Nonlinear effects eliminate this divergence, *e.g.*, if high intensity speckles amplify less than linear theory predicts because their individual backscatter is already saturated. This may occur in the kinetic regime for relatively small Langmuir wave amplitudes: electron trapping reduces the SRS daughter Langmuir wave's damping from Landau's value to ≈ the thermal-electron speckle-width transit rate, ν, once the electron bounce frequency >> ν. If this occurs only in rare speckles, with $I >> I_c$ their backscatter is an augmentation of the thermal source, R_0, with essentially a linear mechanism determining the SRS threshold for the ensemble of speckles. Conversely, if many speckles exhibit a saturated SRS response, then electron trapping will reduce the apparent threshold intensity below I_c. However, for $k\lambda_D > 0.53$, Langmuir wave resonance is not possible and electron trapping pushes the wave further from resonance, reducing G from its linear value even though the wave's damping is reduced. Thus deep into the kinetic regime, and by continuity this will begin at values of $k\lambda_D < 0.53$, electron trapping will raise the onset value of $\langle I \rangle$ above I_c. For still smaller values of $k\lambda_D$, when is $\langle I \rangle \approx I_c$ at onset? The answer, which depends in a simple way on optic f/#, laser wavelength and electron temperature is presented.

Oral Session 2

11:00 am – 12:20 pm

Session Chair: Bedros Afeyan,
Polymath Research

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Where in the (ω- k) Plane Can KEEN Waves Live? Phase Space Distribution Function Partitions, Trapped and Untrapped Particle Orbit Statistics and Energy Density Partitions*

Bedros Afeyan,1 V. Savchenko,1 K. Won1 and T. Johnston2
1Polymath Research, Pleasanton, CA 2INRS-Energie-Materiaux, Quebec, Canada

We will present Vlasov simulation and theoretical results on optical mixing generated Kinetic Electrostatic Electron Nonlinear (KEEN) waves1 with the following specific questions in mind. Where in the (ωDrive-kDrive) plane can KEEN waves be generated and sustained? For what values of drive frequency does a given wavenumber KEEN wave have maximum density response? How different are the Fourier mode compositions of the KEEN waves found in the kλD range (0.1 - 1.0) and the ω/ωp range (0.1 – 2)? What differentiates well-formed from ill-formed KEEN waves in phase space? Can one find a minimal set of distribution function partitions in phase space where each partition has its own specific role to play with respect to the non-stationary yet long lived behavior of undamped multi-mode electrostatic nonlinear high frequency waves? What is unique about the nature of the trapped to untrapped particle orbit statistics in each of these significant partitions? What can be said about the kinetic and potential energy densities in these partitions and in these different Fourier modes that make up KEEN waves? For a given drive amplitude and drive time, can we trace out the locus of the KEEN waves with the largest density response and the edges of where KEEN waves can be excited? Will KEEN waves live outside this range at higher amplitude drives? Can we arrive at sufficient and/or necessary criteria for the identification of a long-lived structure in phase space as being a KEEN wave?

KEEN waves are states of high frequency, nonlinear, kinetic undamped self organization of a plasma which, unlike Landau damping, quasilinear diffusion and O'Neil or BGK modes, live in the spectral gap of traditional plasma physics and involve the trapping, untrapping and retrappping of large portions of their constituent particles in a multimode, largely coherent field emerging out of stochastic (yet self-consistent many body) wave-particle interactions (as opposed to single particle orbits in prescribed fields where large scale diffusion, once untrapping occurs, is almost inevitable).

1 B. Afeyan, et al., Kinetic Electrostatic Electron Nonlinear (KEEN) Waves and their Interactions Driven by the Ponderomotive Force of Crossing Laser Beams, 213, in Proc. Third Intern. Conf. on Inertial Fusion Science and Applications, B. A. Hammel, D. D. Meyerhofer, J. Meyer-Ter-Vehn and H. Azechi, editors, American Nuclear Society, 2004

*This work was supported by the DOE Stockpile Stewardship Academic Alliance PRI Grant DE-FG03-3NA00059.

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Nonlinear Evolution of SRS Coupled with The Langmuir Decay Instability In a Multidimensional Inhomogeneous Plasma

Th. Fouquet [1,2], **D. Pesme** [1], **S. Hüller** [1], **M. Casanova** [2], **and P. Loiseau** [2]
[1] *Centre de Physique Théorique, Ecole Polytechnique*
91128 Palaiseau Cedex, France
[2] *CEA-DIF, BP 12, 91680 Bruyères-le-Châtel, France*

We investigated the nonlinear evolution of SRS by means of numerical simulations carried out with a fluid type code, in the limit where the nonlinear saturation mechanism is the Langmuir Decay Instability (LDI) resulting from the coupling of the Raman generated Langmuir wave with the ion acoustic wave (IAW). We considered the case of an inhomogeneous multidimensional under-quarter critical plasma in the regimes where the Rosenbluth[1] gain factor is sufficiently low, therefore limiting the Langmuir wave amplitude to values such that the electron kinetic effects can be ignored. We have observed that depending on the plasma parameters, the LDI may decrease or, surprisingly, increase the SRS reflectivity. We interpret the latter case as the result of the fact that the small periodic modulations of the electron density profile caused by the LDI generated IAW are able to transform spatial amplification into an absolute instability, as initially observed by D. Nicholson[2], investigated in detail by T.W. Johnston[3], and quantified by M. Casanova et al[4].

1 M. N. Rosenbluth, Phys. Rev. Lett. **29**, 565 (1972)
2 D. R. Nicholson, Phys. Fluids **19**, 889 (1976)
3 G. Picard, T. W. Johnston, Phys. Fluids **28**, 859 (1985)
4 M. Casanova, D. Pesme, T. Fouquet, P. Loiseau and S. Hüller, "Revisiting parametric instabilities in inhomogeneous plasmas", poster presentation, this conference.

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One-dimensional PIC Simulations of Stimulated Raman Scattering. Comparison with Fluid Type Modeling

A. Heron[1], S. Weber[1,2], J. C. Adam[1], T . Fouquet[1,3], S. Huller[1], D. Pesme[1], and C. Riconda[1,2]
1 *Centre de Physique Theorique, Ecole Polytechnique 91128 Palaiseau Cedex, France*
2 *Centre des Lasers Intenses et Applications, Universite Bordeaux 1, 33405 Talence Cedex, France*
3 *CEA DIF, BP 12, 91680 Bruyeres-Le-Chatel, France*

Following previous studies [1-3], we investigated the nonlinear evolution of SRS by means of full PIC simulations in the case of a plasma foil expanding in vacuum. The particles are reflected by the ambipolar potential. One objective of our studies is to classify the regimes for which the nonlinear saturation of SRS results (i) from kinetic effects, (ii) from LDI, or (iii) from both. To do so, we varied in a broad domain the laser intensity, the electron and ion temperatures and the plasma length. In the case where LDI is the saturation mechanism, we then compared the PIC results with a fluid type description corresponding to the coupling of two paraxial equations describing the transverse waves with the Zakharov equations [4].

1 K. Y. Sanbonmatsu, H. X. Vu, B. Bezzerides, and D. F. DuBois, Phys. Rev. Lett. 82, 932 (1999); K. Y. Sanbonmatsu, H. X. Vu, B. Bezzerides, and D. F. DuBois, PoP 7, 1723 (2000).
2 H. X. Vu, D. F. DuBois, and B. Bezzerides, Phys. Rev. Lett. 86, 4306 (2001); H. X. Vu, D. F. DuBois, and B. Bezzerides, PoP 9, 1745 (2002).
3 A. B. Langdon and D. E. Hinkel, Phys. Rev. Lett. 89, 015003 (2002).
4 H. A. Rose, D.F. DuBois, and B. Bezzerides, Phys. Rev. Lett. 58, 2547 (1987); T. Kolber, W. Rozmus, and V.T. Tikhonchuk, Phys. Fluids B 5, 138 (1993); H. A. Rose, PoP 5, 3688 (1998); H. A. Rose, PoP 5, 3876 (1998); H. A. Rose, PoP 6, 476 (1999).

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On the Effect of SSD on Backscattering Instabilities in the Absence of Filamentation/Forward SBS

L. Divol, E. A. Williams, R. L. Berger, D. Hinkel, C. H. Still and A. B. Langdon
Lawrence Livermore National Laboratory, USA

In typical NIF ignition targets, the laser beams propagate through a thin layer of high-Z (gold) hot underdense plasma before its power is converted to X-rays. Stimulated Brillouin and Raman scattering instabilities are in a weakly damped regime with linear amplification gains usually well below 20 (for intensity). Under these conditions of short plasmas with moderate gains, high intensity speckles play a major role for backscattering instabilities. It is well known since the pioneering work of H. Rose (circa 1995) that this situation can lead to significant reflectivity even for gains as low as a few. I will review what is known about the effect of smoothing by spectral dispersion (SSD) in these conditions and quantitatively assess the effect for NIF parameters with fluid simulations of the backscattering using the laser plasma interaction code pF3d.

This work was performed under the auspices of the U.S. Department of Energy by the University of California, Lawrence Livermore National Laboratory under contract No. W-7405-Eng-48.

Evening Invited Talk 1

Speaker: C. Rousseaux
7:00 pm – 8:00 pm

Session Chair: Stefan Hüller,
Ecole Polytechnique

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Experimental Studies of Parametric Instabilities Using Short Pulse Lasers : From High-Intensity Propagation Experiments to sub-ps Thomson Scattering Diagnostic Experiments

Christophe Rousseaux
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With the development of short pulse lasers coupled to 100-J class nanosecond lasers, the interaction of a picosecond pump with preformed, homogeneous and undercritical plasmas can be experimentally studied over a wide range of intensities. In particular, the laser-plasma instabilities (LPI) have been investigated for intensities ranging from those reached in the speckle pattern of a smoothed focal spot of large laser facilities, to relativistic values ($I\lambda^2 > 10^{19}$ Wμm^2/cm^2), relevant for example to the fast ignitor scheme. Both regimes will be addressed in this talk, which will review experiments performed at CEA-Limeil (P102 laser facility) and at LULI (100-TW facility).

As a reminder, the first part of the talk will present measurements obtained some time ago about LPI reflectivities as a function of the pump intensity. It is shown that the reflectivity integrated over the 0.5 ps pulse duration quantitatively agrees with the linear theory (up to the saturated regime) for stimulated Raman backscattering (BSRS), contrary to the stimulated Brillouin backscattering (BSBS) case for which huge discrepancy is observed. The reflectivities, forward-SRS and the transmitted light have been measured up to $2x10^{19}$ Wμm^2/cm^2 in different plasma densities. The transmission rate remains weak, even in low density plasmas (0.05 n_c), essentially because of strong electron parametric instabilities. PIC simulations qualitatively support the experiment, and predict that the plasma should become transparent above ~ 10^{20} Wμm^2/cm^2, a regime where the electron heating is so intense that the Langmuir waves (EPW) get strongly damped.

The second and main part of this presentation will focus on recent experiments where the EPWs and IAWs (ion acoustic waves) driven by the BSRS and BSBS have been spatially and temporally resolved over the 1.5 ps pump duration. The wave number of the electrostatic waves has also been resolved. The interaction takes place in preionized He plasmas and the time resolution is given by the 0.3 ps 3w Thomson probe. The experimental results will be discussed with the help of theoretical models and PIC simulations as follows:
(i) the time-histories of the development of the BSRS-EPWs and the BSBS-IAWs have been simultaneously obtained over the laser pump duration. The BSRS-EPWs are shown to decay suddenly around the top of the pulse; electron kinetic heating and trapping play a major role for SRS saturation in this short time scale, contrary to ion dynamics. This is

supported both by low intensity experiment and PIC simulations. The evolution of the EPW wave number spectrum mostly indicates significant sidescattering;
(ii) the damping of the IAWs has been directly measured for He, N_2 and for two hydrocarbon gases, methane CH_4 and propane C_3H_8. The theoretical comparison using linearized Vlasov-Poisson calculations shows good agreement for pure species, contrary to the multispecies cases;
(iii) finally, we will present some atypical, interesting spectra obtained during these experiments, not yet completely analyzed. On the one hand, in the development phase of the instabilities, the kspectra exhibit during a short ~ 1 ps time interval a very broad structure (in wavelength) possibly related to the "streak" component recently evidenced in simulations [L. Yin *et al.*, Phys. Rev. E **73**, 025401(R) (2006) and H.X. Vu *et al.*, Phys. Rev. Lett. **95**, 245003 (2005)]. On the other hand, thermal Thomson scattering on EPWs has been attempted, yielding, at high intensity, surprisingly spatially asymmetrical spectra.

Poster Session 1

Session Chair: Stefan Hüller,
Ecole Polytechnique

8:00 pm – 11:00 pm

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One Dimensional Theory of Laser Acceleration of Light Ion Beams from the Interaction of Ultrahigh Intensity Lasers with Layered Targets*

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Recent experiments at the LANL Trident facility have demonstrated for the first time that laser-driven quasi-monoenergetic ion beams may be produced from the interaction of an ultra-intense laser with a composite target comprising a heavy ion substrate with a thin layer of light ions on the rear surface. An analytic model is obtained that predicts how properties of these beams, including beam energy and energy spread, vary with changes to substrate material and light ion layer composition and thickness. Key dimensionless parameters controlling the properties of the beam are derived and validation of the model is performed using particle-in-cell simulations and experimental data.

*This work was performed under the auspices of the U.S. Department of Energy (DOE) by the University of California Los Alamos National Laboratory under contract W-7405-ENG-36. Work supported by the LANL Laboratory Directed Research and Development (LDRD) program.
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PIC Simulation of Fast Ignition Targets with OSIRIS

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Understanding transport of fast electrons generated by the ignition laser pulse at the critical surface to the target core is essential to the success of fast ignitor concept. Results of 2.5D PIC simulations of scaled fast ignitor targets along with code modifications made to the massively parallel PIC code OSIRIS for fast ignition relevant regimes are presented. We look at the effect of target temperature and density profiles on the laser envelop and how it affects electron transport. We also look at how feedback from a resistive core affects electron transport. Code modifications include deposition and interpolation schemes that have significantly better energy conservation, a mock up of target (resistive) core, and specialized diagnostics. The improved energy conservation is particularly important for the large range of densities necessary for simulation of fast ignition targets.

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Implicit Scoping Calculations for Fast Ignition

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The limited classical coupling of hot electrons to background plasma seen in recent implicit calculations[1] of cone target dynamics suggests a need for alternate approaches for enhanced coupling of the laser to the background plasma. Recent studies have involved laser deposition and hot electron transport in cone-fiber targets with possible magnetic confinement, and energy deposition in compressed target cores through a fast ion intermediary. Preliminary results from implicit simulations of such configurations will be discussed.

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1. R. J. Mason, Phys. Rev. Lett. **96** 035001 (2006).

*Work supported by the USDOE.

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Nike Experiments on Shock Propagations with a Short Spike Prepulse

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Theoretical [1] and experimental [2] studies have demonstrated that the growth of hydrodynamic instabilities was reduced when a spike pulse was used before the main drive pulse. At Nike KrF laser facility, planar CH targets were irradiated with a spike prepulse followed by a main pulse (4 ns duration at ~ 40 TW/ cm^2) to study the shock propagations. The spike was approximately Gaussian shaped with 300 ps FWHM and up to 15% of the main pulse intensity. Using a VISAR diagnostic, it was observed that the shock wave from the spike was rapidly decaying and overtaken by the later-on shock wave from the main beam. The decaying shock velocity was measured with VISAR fringes and in good agreement with analytic predictions [3] of impulsive loading. The shock timing for simultaneous arrival of spike and main shocks at target rear surface was confirmed with VISAR. The self-emission from the shock front was resolved by temperature-calibrated diagnostics with a streak camera and photomultipliers. The reflectivity was measured at the shock front with VISAR. The shock temperature, by the assumption of gray-body radiation, was deduced from the time-resolved measurements of the self-emission and the reflectivity. The temperature was scanned with respect to the decaying shock speed and compared with predictions of SESAME EOS.

Work supported by DoE and DoD and performed at the Naval Research Laboratory.

[1] N. Metzler *et al.*, Phys. Plasmas **6**, 3283 (1999); **9**, 5050 (2002); **10**, 1897 (2003); V. N. Goncharov *et al.*, Phys. Plasmas **10**, 1906 (2003).
[2] J. Knauer *et al.*, Phys. Plasmas **12**, 056306 (2005); T. Collins *et al.*, Phys. Plasmas **11**, 1569 (2004);
[3] A. L. Velikovich *et al.*, Phys. Plasmas **10**, 3270 (2003).

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Ignition Design for NIF and Reemission Ball Diagnostic for early time Symmetry Measurements(U)

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One of the recent NIF designs uses shine shields in a hohlraum to achieve high capsule gain with a lower amount of laser energy.[1] We examine our own design of such a hohlraum and capsule configuration and discuss the issues encountered. Reemission ball has been used in the past to measure early time capsule symmetry for experiments done on NOVA.[2-3] Livermore scientists are now pursuing this concept to study early time symmetry on NIF.[4] Here we examine the predicted capsule symmetry for our NIF capsule using the reemit technique. Issues related to the three-dimensional nature of the reemit diagnostic will be discussed. Issues such as the viewing holes in the hohlraum wall will be addressed by applying a three-dimensional view-factor code.

1. D. Callahan et al., presented at the 2005 plasma APS meeting in Denver, CO.
2. G. R. Magelssen et al., Phys. Rev. E 57, pg. 4663 (1998).
3. N. D. Deamater et al., Phys. Rev. E 53, 5240 (1996).
4. Don Meeker, private communication, LLNL.

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Laser Imprint Suppression with High-Z Layers at High Foot Intensities

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We are carrying out experiments on imprint on the Nike KrF laser with induced spatial incoherence (ISI) smoothing. Most of the imprint occurs during the initial low-intensity ("foot") part of the pulse, which is necessary to compress the target to achieve high gain. It has been found previously that a thin high-Z overcoat on the laser side of the target can be effective in suppressing imprint*. The present experiments are designed to extend this method to higher foot intensities (~10^{13} W/cm^2), approaching those of the current high gain pellet designs. Measurements of Raleigh-Taylor (RT) amplified areal mass non-uniformity are made by face-on x-ray radiography using Bragg reflection from a curved crystal coupled to an x-ray streak camera. X-ray flux from the high-Z layer is monitored using absolutely calibrated time-resolved x-ray spectrometers. Simultaneous side-on radiography using a curved crystal allows target trajectory measurement for comparison with simulations. The effect of the high-Z layers of varying thicknesses on ISI imprint as well as re-imposed ripple growth will be presented for two different materials (Au and Pd).

This work is supported by the U. S. Department of Energy/NNSA.
*S. P. Obenschain et al. Phys. Plasmas 9, 2234 (2002)

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Development of the Electron Transport Model in Radiation-Hydrodynamic Codes

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With the development of a laser modelling capability, our radiation-hydrodynamics code CORVUS is becoming useful for simulation of laser-plasma experiments. CORVUS is a 2D ALE (Arbitrary Lagrangian-Eulerian) code that provides improved performance in hohlraum and ICF simulations, where time-step collapse due to mesh-movement is catastrophic in pure Lagrangian codes. Whilst the handling of radiation in the code is quite advanced, including NLTE opacities, the electron transport is still handled using a diffusion model built on the classic flux-limited Spitzer-Harm approximation.

Anticipating the continued deployment of laser experiments of increased intensity at AWE and elsewhere, we are seeking to improve the electron transport in a practical way. We describe some initial development in moving beyond Spitzer-Harm by including the transport physics more faithfully, using a nonlocal-flux approach developed from models in the literature. Some gasbag experiments on the HELEN laser are simulated as a preliminary test of the code.

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Exploiting Sparsity and Morphological Diversity to Characterize the Uniformity of Spherical Shells in ICF Targets and their Radiation Driven Implosions*

Bedros Afeyan,[1] K. Won,[1] J. L. Starck,[2] R. Stephens,[3] E. Mapoles,[4] M. Johnson,[4] S. Haan,[4] M. Cuneo[5] and G. Bennett[5]
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We will show how spherical harmonics, isotropic wavelet transforms and curvelets can be used in combination to separate out morphologically diverse elements that make up the surface imperfections of ICF targets. We will show spherical interferometry and atomic force microscopy data on CH and Be shells which are analyzed using these morphological diversity and sparsity exploiting tools. Long thin strips and full Sphere Map data will be analyzed in Euclidean and Spherical decompositions. Features with global support are captured with the Ylm's, ribbon like structures by curvelets and (near) point localized bumps by isotropic wavelet transforms. How to control the number of iterations and optimally choose thresholding criteria will be given.

The statistics of the locations, sizes and heights of the surface nonuniformities will be extracted from such sparse representations and a global assessment made of their contributions to hydrodynamic instabilities such as Rayleigh-Taylor and Richtmeyer-Meshkov. Implodability criteria will be given using Haan growth factors from specific target designs.

In addition, X ray illumination uniformity in hohlraums will be analyzed using wavelet techniques uniquely suited to the characterization of the Legendre polynomial decomposition of the shell thickness averaged nonuniformities of X ray point projection backlighting images of imploding shells. These (1+1)D undecimated, isotropic wavelet transform techniques applied to shell unwrapped images give rise to excellent denoising results which well exceed those obtained using curvelets, which are the next best thing.

Two codes which incapsulate this work will be introduced. These interactive GUI based tools are called MODEM (Morphological Diversity Extraction Method) and MASIS (Multiresolution Analysis of Shell Implosion Symmetry).

*This work was funded in part by General Atomics (applications of MODEM) and Sandia National Laboratories (applications of MASIS).

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Revisiting the Parametric Instabilities in an Inhomogeneous Plasma

M. Casanova [1], D. Pesme [2], T. Fouquet [1,2], P. Loiseau [1], S. Hüller [2]
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The question of parametric instabilities in an inhomogeneous plasma remains an important issue, because the linear behavior of stimulated Raman scattering (SRS) and stimulated Brillouin scattering (SBS) depends dramatically on the details of the inhomogeneity. In most cases, the linear behavior of these scattering instabilities may be modeled by the following coupled-mode equations

$$\begin{cases} \left(\dfrac{\partial}{\partial t} + V_{g1}\dfrac{\partial}{\partial z}\right)a_1 = \gamma_0(z)a_2^* \\ \left(\dfrac{\partial}{\partial t} + V_{g2}\dfrac{\partial}{\partial z} + iV_{g2}\Delta k(z)\right)a_2 = \gamma_0(z)a_1^* \end{cases}$$

where the complex envelope amplitudes a_1 and a_2 respectively stand for the backscattered wave and the longitudinal wave. V_{g1} and V_{g2} denote the z components of the group velocities. We restricted ourselves to the case $V_{g1}V_{g2} < 0$ corresponding to SRS and SBS backscatterings. The inhomogeneity is taken into account via (1) the wave-vector mismatch $\Delta k(z)$, and (2) the coupling constant $\gamma_0(z)$. We considered systems in which this coupling constant is a slowly varying function of the spatial coordinate z, in which case the linear behaviour of the decay waves depends essentially on the functional form of the mismatch $\Delta k(z)$. M.N. Rosenbluth has shown in his seminal paper[1] that in the linear limit $\Delta k(z) = K'(z - z_0)$, after a transient time, the decay waves may only grow in space, their spatial amplification then being limited by the so-called Rosenbluth gain factor. On the other hand, it is now well known[2] that this result is not robust: small modifications of the functional form of $\Delta k(z)$ are able to restore the temporal exponential growth, characteristic of an absolute instability. We carried out extensive numerical simulations in the case $\Delta k(z) = K'(z - z_0) \pm K_m \sin((z - z_0)/L_m)$, where K_m and L_m are the two parameters characterizing a sinusoidal modulation of the inhomogeneity. We revisited pioneering works[3-4], extending and quantifying their results. We found that extremely small values of the modulation amplitude can restore the absolute instability. The physical consequences for SRS and SBS will be discussed.

[1] M. N. Rosenbluth, Phys. Rev. Lett. **29**, 565 (1972)
[2] D. Pesme, G. Laval, and R. Pellat, Phys. Rev. Lett. **31**, 203 (1973); R. White, P. Kaw, D. Pesme, M. N. Rosenbluth, G. Laval, R. Huff, and R. Varma, Nucl. Fusion **14**, 45 (1974)
[3] D. R. Nicholson, Phys. Fluids **19**, 889 (1976)
[4] G. Picard, T. W. Johnston, Phys. Fluids **28**, 859 (1985)

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Extensive Simulations Concerning the Nonlinear Evolution of SRS Coupled with The Langmuir Decay Instability in a Multidimensional Inhomogeneous Plasma

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The goal is to investigate the nonlinear evolution of SRS by means of numerical simulations carried out with a fluid type code, in the limit where the nonlinear saturation mechanism is the Langmuir Decay Instability (LDI) resulting from the coupling of the Raman generated Langmuir wave with the ion acoustic wave (IAW). We considered the case of an inhomogeneous multidimensional under-quarter critical plasma in the regimes where the Rosenbluth[1] gain factor is sufficiently low, therefore limiting the Langmuir wave amplitude to values such that the electron kinetic effects can be ignored. We have observed that depending on the plasma parameters, the LDI may decrease or, surprisingly, increase the SRS reflectivity. We interpret the latter case as the result of the fact that the small periodic modulations of the electron density profile caused by the LDI generated IAW are able to transform spatial amplification into an absolute instability, as initially observed by D. Nicholson[2], investigated in detail by T.W. Johnston[3], and quantified by M. Casanova et al[4]. Many simulations for a monospeckle and a Random Phase Plate laser beam will be presented.

[1] M. N. Rosenbluth, Phys. Rev. Lett. **29**, 565 (1972)
[2] D. R. Nicholson, Phys. Fluids **19**, 889 (1976)
[3] G. Picard, T. W. Johnston, Phys. Fluids **28**, 859 (1985)
[4] M. Casanova, D. Pesme, T. Fouquet, P. Loiseau and S. Hüller, "Revisiting parametric instabilities in inhomogeneous plasmas", poster presentation, this conference.

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Particle In Cell Simulations of the Two Plasmon Decay Instability For Plane Waves in Inhomogeneous Plasmas

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1 University of California, Los Angeles, Los Angeles, CA
2 Polymath Research Inc, Pleasanton, CA

A particle-in-cell code (**OSIRIS**) is used to investigate the two-plasmon decay instability in nonuniform plasmas of various density profiles. We find good agreement between the simulation and linear theory by Afeyan and Williams (Phys. Plas. **4**, 3827, 1997.) under a variety of laser and plasma conditions relevant to ICF. So far the theory has been tested for linear density profiles and parabolic density profiles where the perfect phase matching condition (PPMP) is at the parabolic peak density. We will also test the theory's predictions concerning growth rates and eigeneconditions when the PPMP is in the transition region between the peak density of the parabolic profile and down on the flanks where strictly linear profile behavior is recovered. This is done by performing a series of simulations by gradually decreasing the peak density from a value considerably above quarter critical to one just at quarter critical while keeping the scale lengths the same. These simulations allow a check on linear theory, and also demonstrate the ability of PIC codes to study this instability in small regions of ICF relevant targets.

P-Polarized obliquely incident lasers will also be considered where the theory predicts a non-equal ratio between thresholds for the excitation of modes which correspond to positive and negative $k_\perp$ values of equal magnitude. This symmetry breaking in transverse momentum has never been verified in simulations before.

This leaves S polarized laser $2\omega_p$ simulations and the Mixed Polarization High Frequency (MPHF) instability to be simulated which is the proper unified theory of $2\omega_p$ and Raman scattering in the vanishing $k_\perp$ limit (Afeyan and Williams, *Phys. Rev. Lett.*, **75**, 4218, (1995) and *Phys. Plasmas*, **4**, 3845, (1997).). The challenges of extending the simulations to 3D where these latter phenomena can be studied numerically will also be discussed.

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3ω Laser Beam Propagation in High Temperatures and Long-Scale Length Plasmas

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A study of the relevant laser-plasma interaction processes in a long-scale length high-temperature plasma will be presented. The interaction physics is studied along the axis of a 2-mm-long hohlraum where the plasma has been well-characterized using Thomson scattering; a peak electron temperature of 3.5 keV has been measured. The electron temperature measurements validate the HYDRA flux-limited diffusion model with a flux limiter of f=0.05. The 3ω laser light that propagates through this plasma is measured with a recently implemented transmitted beam diagnostic which shows good propagation (T>70%) for NIF/ICF relevant intensities ($I < 2x10^{15}$ $W\text{-}cm^{-2}$) and significant beam spray for intensities above this point. Detailed hydrodynamic and laser-plasma interaction simulations capture the stimulated Brillouin, Stimulated Raman, and filamentation thresholds providing significant confidence that our models used for ignition designs can correctly describe the energy loss and beam propagation through the under dense NIF hohlraums. Future LPI experiments using variations on this target platform will be discussed.

Tuesday, June 6, 2006

9:00 -	10:00 AM	Invited Talk – M. Tabak Session Chair: J. Fernández
10:00 -	10:40 AM	Oral Session 3
10:40 -	11:00 AM	Coffee Break
11:00 -	12:20 PM	Oral Session 4 Session Chair: J. Fernández
12:30 -	1:30 PM	Lunch
1:30 -	3:00 PM	Focus Group Short Pulse & Fast Ignition Discussions
7:00 -	8:00 PM	Invited Talk – C. Geddes Session Chair: J. Kline
8:00 -	8:15 PM	Business Meeting
8:15 -	11:00 PM	Poster Session

Morning Invited Talk 2

Speaker: M. Tabak
9:00 am – 10:00 am

Session Chair: Juan Fernández, *Los Alamos National Laboratory*

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Issues in Fast Ignition*

M. Tabak
Lawrence Livermore National Laboratory

Scientists around the world have studied Fast Ignition, an alternate form of inertial fusion, with increasing intensity over the past decade. In this scheme, the fuel is first compressed by a long pulse driver and then ignited by the short pulse laser. Due to technological advances, external energy sources (such as short pulse lasers) can focus intensity equivalent to that produced by the hydrodynamic stagnation of conventional inertial fusion capsules. This review will discuss the ignition requirements and gain curves starting from simple models and then describing how these are modified, as more detailed physics understanding is included. The critical design issues revolve around two questions: How can we efficiently assemble the compressed fuel? And how can we deliver the power from the driver to the ignition region? We will describe schemes to shorten the distance between the critical surface, where the high intensity laser deposits its energy into relativistic electrons, and the ignition region. We will review the theoretical and experimental status of the "hole boring" and "cone focus" schemes. In the hole-boring scheme an additional laser beam's ponderomotive light pressure is used to push the coronal plasma out of the ignition laser's beam path. For the cone focus scheme the implosion target is manufactured such that a vacuum path for the ignition laser is maintained during the implosion phase. We will describe what is known about the efficiency with which light couples to a plasma and the transport properties of the relativistic electrons that are generated during the interaction. An alternate route to coupling the energy to the ignition region passes through an intermediate stage where protons are generated from a virtual cathode and then focused into the compressed fuel . Experiments and modeling of the transport of proton and electron beams will be described. Finally, the status of the project is compared with our requirements for success. Future research directions will be outlined.

*This work was performed under the auspices of the U.S. Department of Energy by the University of California, Lawrence Livermore National Laboratory under contract No. W-7405-E. G-48.

Oral Session 3

10:00 am – 10:40 am

Session Chair: Juan Fernández, *Los Alamos National Laboratory*

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Laboratory Demonstration of e+e– Pair-Plasma Production on OMEGA EP

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On the basis of implicit-hybrid, particle-in-cell (PIC) calculations, it is shown that positrons of sufficient number and density may be created for OMEGA EP parameters so that they behave as a collective, many-body system (to our knowledge, a convincing demonstration of e+e– pair-plasma production in the laboratory has yet to be achieved). We estimate that between 1011 and 1012 positrons can be made on OMEGA EP with the Bethe–Heitler conversion of hard x-ray bremsstrahlung,1 assuming a total laser energy of 5 kJ and a 40% conversion efficienc of laser energy into hot electrons. Once produced, the positrons rapi y expand, carrying a neutralizing cloud of electrons with them.2 For this expanding e+e– cloud to be considered a plasma, there must be many particles in a Debye sphere, and the cloud must be many Debye lengths in size. If the cloud is allowed to freely expand, these conditions are unlikely to be satisfied. We show that sufficient confinement can be obtained by using one OMEGA EP beam to magnetize the target. To confirm the production of an e+e– plasma, we show how peculiarities in the linear mode structure3 can be exploited.

This work was supported by the U.S. Department of Energy Office of Inertial Confinement Fusion under Cooperative Agreement No. DE-FC52-92SF19460, the University of Rochester, and the ew 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. J. D. Bjorken and S. D. Drell, *Relativistic Quantum Mechanics* (McGraw-Hill, . ew York, 1964); D. A. Gryaznykh, Ya. Z. Kandiev, and V. A. Lykov, JETP Lett. **67**, 257 (1998); K. Nakashima and H. Takabe, Phys. Plasmas **9**, 1505 (2002).
2 E. P. Liang, S. C. Wilks, and M. Tabak, Phys. Rev. Lett. **81**, 4887 (1998).
3. G. P. Zank and R. G. Greaves, Phys. Rev. E **51**, 6079 (1995).

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Absorption and Energy Partition of Short Laser Pulses in the Relativistic Regime

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We present the first direct measurements of energy absorption at laser intensities of 10^{17} - 10^{20} W/cm^2. A surprisingly high value of absorption (~ 90%) was observed for P - polarized laser pulses at oblique incidence in the ultra-relativistic regime. The spatial distributions of hot electrons measured by dosimeters show that the dominant absorption mechanism changes with intensity: from resonant absorption at ≤ 10^{18} W/cm^2, to J×B heating at ~ 10^{19} W/cm^2, and to vacuum heating at ~ 10^{20} W/cm^2. Furthermore, the partition of absorbed laser energy into thermal and non-thermal electrons was studied at 10^{17} – 10^{19} W/cm^2 by various diagnostics including an electron spectrometer, an optical spectrometer and a dual-crystal von Hámos spectrometer coupled with an ultrafast x-ray streak camera. The time history of Ti Kα emission reasonably agrees with calculated thermal-hot electron equilibration time based on measured hot electron temperature. Unexpected enhanced population of thermal electrons was observed as the intensity increases to 10^{19} W/cm^2, which we think is due to collisional damping of hot electrons in combination with the expansion of the plasma.

Oral Session 4

11:00 am – 12:20 pm

Session Chair: Juan Fernández, *Los Alamos National Laboratory*

36th Annual Anomalous Absorption Conference
Jackson Hole, Wyoming, USA
June 4-9, 2006

Observation of Amplification of a 1ps Pulse by SRS of a 1 ns Pulse in a Plasma with Conditions Relevant to Pulse Compression

R. K. Kirkwood, S. C. Wilks, E. Dewald, N. Meezan, C. Niemann, O. L. Landen, *LLNL*, **J. Wurtele,** *A. E. Chairman*, **R. Lindberg**, *UC Berkeley/LBL*, **N. J. Fisch, V. M. Malkin**, *Princeton University*

We have demonstrated the amplification of a 1 ps, 1200 nm, probe pulse when counter propagating with a 1ns, 1.1 x 10^{15} W/cm^2, 1064 nm pump pulse, in a He gas plasma created by the pump. When the gas and plasma density is adjusted to match the resonance condition for the probe to seed the stimulated Raman scattering (SRS) of the pump (~ 1 x 10^{19} e/cm^3) we find that the transmitted probe energy is enhanced by up to 37x of its value off resonance, and that as much as 4 mJ of energy is transferred. This is the first demonstration that a 1ns pump beam can significantly amplify a ultra short pulse by SRS in a plasma with conditions that can survive irradiation by the pump, and which is therefore attractive for compression of the pump when the interaction length is increased. Experiments both at reduced pump intensity, and with an 1124 nm wavelength probe interacting in a 2.5 x 10^{18} e/ cm^3 plasma, also show a strong scaling of amplification with the resonant density and probe wavelength, and a weaker scaling with pump intensity. Measurements of the un-seeded SRS backscatter show similar scaling with density suggesting that the scattering waves are non-linearly saturated in this regime. Scans of relative beam timing and plasma density will also be discussed as will considerations for compression of 1ns pulses.

This Work was performed under the auspices of the U.S. Dept. of Energy by University of California Lawrence Livermore National Laboratory under contract No. W-7405-ENG-48.

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Cone Targets Revisited

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Hot electron deposition and transport in planar and cone targets have been given recent study[1,2] via implicit plasma simulation. This talk will reexamine the background heating mechanisms revealed in cone targets by these calculations, i.e. joule heating and direct electron drag against the cold background. Attention will also be given to transport through alternate cone target configurations (structured cones and modified core coronal conditions).

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Filamentation of Fast-Ignition Electron Transport in Plasmas: Spatial Growth and Absolute Modes

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A comprehensive dispersion relation for relativistic electron-beam microinstabilities has been developed. This dispersion relation includes both electrostatic and electromagnetic terms, allows arbitrary directions and complex values for the perturbation wave vector, and can incorporate fully relativistic Maxwell–Boltzman–Juttner distribution functions or approximations thereto. In this talk, the relation is used to explore some aspects of beam filamentation for parameters relevant to fast ignition (FI). The FI electron beam originates with perturbations imposed by laser and plasma nonuniformities near critical density and must then propagate through progressively denser plasmas to the compressed core, where its energy is deposited. Weibel-like filamentation instabilities are often seen in simulations of this process. Previous analyses of these instabilities have determined temporal growth rates.[1,2] However, since filaments are initiated in the generation region near critical density and grow as the beam propagates inward, spatial growth rates are more appropriate to this problem. In determining these growth rates it is necessary to distinguish complex values of the wave vector corresponding to growth from those corresponding to evanescent modes.[3] It is found that spatial growth can give way to absolutely growing modes, which can be expected to dominate the filamentation process regardless of the perturbations imposed by beam generation. These results determine the essential physics and the spatial and temporal scales pertaining to the fastest growing modes, and thus the necessary resolution and appropriate physics approximations for efficient simulation of these modes. This work should further be useful in benchmarking codes such as LSP.

This work was supported by the U.S. Department of Energy Office of Inertial Confinement Fusion under Cooperative Agreement No. DE-FC52-92SF19460, the University of Rochester, and the New York State Energy Research and Development Authority. The support of DOE does not constitute an endorsement by DOE of the views expressed in this article.

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Transport Near the Critical Density Surface in Direct-Drive ICF Plasmas

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In direct-drive inertial confinement fusion (ICF), the characteristic features of the plasma corona are steep gradients of plasma density and temperature in the region close to the critical density surface. Modeling of laser absorption and heat transport in direct-drive ICF targets strongly depends on the laser–plasma interaction in this near-critical-density region, which includes turning points for laser beams.

In experiments on the OMEGA Laser System, laser beams are randomized in space by distributed phase plates and randomized in time by smoothing by spectral dispersion. This beam incoherence produces an ensemble of moving laser hot spots in plasmas that generate density depressions and consequently generate magnetic fields due to the crossing gradients of density and temperature. Another feature that influences the interaction in the near-critical-density region is the small-scale density grating produced by the interference of multiple laser beams.

The numerical modeling has been performed using the laser-plasma interaction code[1] describing nonlinear beam propagation near the beam turning points close to the critical density surface. The magnetic field structure in this region has been calculated, and its influence on the electron heat transport is demonstrated. The impact of this transport modification on hydrodynamic modeling is discussed.

This work was supported by the U.S. Department of Energy Office of Inertial Confinement Fusion under Cooperative Agreement No. DE-FC52-92SF19460, the University of Rochester, and the New York State Energy Research and Development Authority. The support of DOE does not constitute an endorsement by DOE of the views expressed in this article.

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Evening Invited Talk 2

Speaker: C. Geddes
7:00 pm – 8:00 pm

Session Chair: John Kline, *Los Alamos National Laboratory*

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Wakefield Accelerators for Ultrafast Particle and Radiation Sources Using Ultrashort-Pulse Lasers

C.G.R. Geddes, E. Esarey, B. Nagler, K. Nakamura, C.B. Schroeder, C. Toth, J. van Tilborg, W.P. Leemans, *LBNL*
E. Michel, T. Cowan, *UNR*
A.J. Gonsalves, S. M. Hooker, *Oxford University, UK*
D. Bruhwiler, *Tech -X,* **J. Cary,** *Tech - X & U. Colorado*

Current particle accelerators for radiation sources, high energy physics, and other applications are typically limited to accelerating gradients near 50 MV/m to avoid material breakdown, resulting in bulky, expensive machines. The cm wavelength of the RF accelerating structures also require beam manipulation to produce fs-scale radiation. A compact technology for generating intense energetic electron beams and synchronized femtosecond radiation sources is plasma acceleration using high energy density lasers.

The physics, research status, and challenges of laser wakefield based accelerators and radiation sources will be discussed. The radiation pressure of an intense laser pulse drives a space charge wave in a plasma, producing acceleration gradients on the order of 100 GV/m and micron wavelength accelerating structures for femtosecond beams. To drive such structures, short pulse lasers are used (40fs, 40 TW, $I=10^{18}$-10^{19} W/cm^2) so that the ponderomotive force resonantly drives the wave ($L_{laser}\sim c/\omega_p$) in cold, low density plasmas ($T_e\sim 10$ eV, $n_e\sim 10^{18}$ cm^{-3}). Structured plasmas (channels) are used to guide this drive pulse, maintaining the accelerating field beyond the laser diffraction range. Acceleration limits include guiding, electron trapping, and dephasing.

Experiments have rapidly progressed beyond the initial demonstration of high accelerating gradients. Recently, electron beams of narrow energy spread and good emittance have been produced at several facilities including ours by extending the acceleration distance to match the dephasing length over which the particles outrun the wave. In the past year, acceleration distance has been extended to cm-scale using channels at LBNL, resulting in energies up to 1 GeV. Production of THz and X-ray radiation have also been observed, and THz has used to verify that the bunches are fs in duration. With these advances, laser accelerators are of increasing interest for applications. Particle and fluid models are used due to the highly nonlinear regime of operation, and these results are discussed in parallel with the experiments.

Challenges include control and reproducibility of the electron beam, scaling to higher energies, and detailed modeling to understand what optimizations are available. In particular, injection of particles into the wave must be accurately controlled, and shot to shot variation must be reduced. Accurate modeling of three-dimensional problems of centimeter scale presents additional challenges.

Supported by U.S. Dept. of Energy contracts DE-AC02-05CH11231, DE-FG03-95ER40926, DE-FG02-01ER41178, DE-FG02-03ER83857, SciDAC, INCITE, and NSF 0113907.

Poster Session 2

8:15 pm – 11:00 pm

Session Chair: John Kline, *Los Alamos National Laboratory*

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Prospects for 100+ GeV Laser Wakefield Accelerator Stages

Wei Lu, M. Tzoufras, F. S. Tsung, C. Joshi, W. B. Mori[1]
University of California at Los Angeles

J. Vieira, R. A. Fonseca, and L. O. Silva
Instituto Superior Technico, Portugal

The extraordinary ability of space-charge waves in plasmas to accelerate charged particles at gradients that are orders of magnitude greater than in current accelerators has been well documented. We show here that 100TW to 2000TW class lasers can excite large amplitude wakefields and be stably self-guided in very underdense plasmas to produce 1 to 10 GeV mono-energetic, self-injected electron beams with nCs of charge. For such powers the plasma wakes can be excited by the nearly complete blowout, i.e., expulsion, of plasma electrons by the radiation pressure of a short pulse laser. The proposed regime is distinct from the ``bubble regime" in that it advocates using lower densities and wider spot sizes while keeping the intensity relatively constant in order to increase the output electron beam energy and keep the efficiency high. Our theoretical results are verified by three-dimensional particle-in-cell simulations. Prospects for extrapolating this regime towards electron energies beyond 100 GeV will be described.

The work is supported by DOE under grants DE-FC02-01ER41179, De-FG02-03ER54721, DE-FG03-92-ER4727 and DE-FG03-NA0065, by NSF under grant Phy-0321345, and by FCT (Portugal). The simulations are performed on Dawson cluster, maintained locally by UCLA/ATS, and on the IBM SP @ NERSC under mp113 and gc2.

[1] This presentation will be given by W. B. Mori.

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Design Study for a Table-Top VUV/X-ray FEL Driven by Laser Accelerated Electron Beams

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M. Geissler, J. Meyer-ter-Vehn
S. Karsch, K. Schmid, L. Veisz, F. Krausz
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S. Reiche, *UCLA, USA*

The recent achievement of laser acceleration of intense quasi-monoenergetic electron bunches in the 100 MeV energy range and above has triggered discussions for the conversion of the electron energy into X-ray pulses of unprecedented brilliance. Compared to conventional linear accelerators electron acceleration by few-cycle TW lasers is capable of providing ultra-high beam currents of up to several 100 kA. However, although the spatio-temporal source dimensions are well-confined within one plasma period (i.e., of the order of the focal parameters of the laser pulse or few μm and fs) and thus beam emittances are competitive, divergence and energy spread observed in the first experiments require a certain attention.

We now propose to utilize such laser-accelerated electron beams to realize a table-top free-electron laser (SASE FEL) based on a magnetic undulator. This approach strongly benefits from the ultra-high electron current as it might allow for reaching saturation on a few-meter scale for an mm-scale period undulator design. Regarding the comparatively low electron energies such short undulator periods are mandatory for entering the X-ray regime.

In this paper we present our first basic design considerations based upon analytical scaling and elaborate simulations (3D PIC and GENESIS 1.3) as well as the status of the experimental work in Munich. It concerns laser acceleration as well as undulator and electron beam optics development, where components are tested at the conventional 800 MeV electron accelerator MAMI. In contrast to the large-scale XFELs, which will be dedicated user facilities, our aim is the delivery of a proof-of-principle 'table-top' FEL, starting in the VUV range.

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Gold Influx in Laser-Driven Hohlraums

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Radiation cases for laser-driven Inertial Confinement Fusion experiments have long been known to be subject to the erosion of the high-atomic-number (typically gold) wall that generates the x-ray drive for imploding the fusion capsule. The result of this wall ablation is that the source of the x-rays, the laser-irradiated gold, moves during the laser pulse causing concern for the symmetry of the x-ray drive on the fuel capsule. Experiments at the OMEGA laser have been performed and show the rate of gold influx as a function of time for both vacuum and gas-filled hohlraums. Single-ended hohlraum targets are driven with 4.3 kJ for 6 ns during a continuous pulse with irradiance on the wall $< \sim 2 \times 10^{14}$ W/cm^2. The targets have a diameter of 1.6 mm and a length of 1.2 mm.

Vacuum hohlraums fill within 5 ns after the relatively soft laser drive begins. A gas fill of 1 atm mitigates the effect. At the peak of the laser drive, an 800-μm clear channel remains on axis in the gas-filled target, as demonstrated by axial imaging of self-emission of the gold. This is predicted by numerical simulations that show modest influx for nearly 9 ns. Axial backlighting of the hohlraum through a plastic or beryllium window has been accomplished at times as late as 14 ns -- ~2/3 the pulse length of ignition experiments. Regardless of backlighter energy, significant absorption of backlighter photons is observed at times as early as 10 ns. Through comparison with radiography of undriven hohlraums, we measure the transmission, from which the line-integrated density ρr may be determined in a time-dependent fashion. In a related experiment, orthogonal x-ray imaging shows laser-illuminated gold streaming from the laser entrance hole. The velocity of this material is compared to the ion sound speed and the velocity of radial flow in the vacuum hohlraums.

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Planar Rayleigh-Taylor and Feedthrough Experiments with CHGe on Omega

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We present recent results concerning Rayleigh-Taylor and feedthrough hydrodynamic instabilities on CHGe, which is the chosen ablator material for the LMJ ignition target. We used a rugby-shaped hohlraum in which a hole was drilled on the side. Modulated CHGe samples were placed on that side hole in order to be irradiated by a hohlraum drive.

Simultaneous side on and face on radiographies were performed, as well as drive characterization using broadband X-ray spectrometers Dante and DMX. Additional shock breakout shots were performed in order to measure the radiative temperature incoming on the sample.

We find that hohlraum simulations are in a good agreement within a few eV with Dante measurements near the laser entrance holes. However, RT growth and acceleration data are coherent with each other but are in agreement with a reduced flux (T_r needs to be lowered about 15%) and hardened spectrum simulations. Only the second harmonic of perturbations seems to agree with full flux simulations, revealing the sensitivity of the experiment to Au M-band.

DMX temperature measurements through an extra diagnostic hole on shock breakout targets confirms that radiative temperature is lowered in the vicinity of the sample under study.

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Effects of a Prepulse on the Performance and Stability of Direct-Drive Laser Fusion Targets*

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Prepulses –or pickets or spikes- have been presented recently as a tool for mitigation of the Rayleigh-Taylor instabilities in direct-drive laser fusion targets. This work takes a critical look at this claim and suggests that especially in the case of the relaxation type prepulse[1] the main effects of prepulses could be to lower the fuel adiabat (compared to the case without prepulse), thereby increasing the gain and the observed stabilization of prepulses could be due in fact to gain recovery in the presence of a strong stabilizing foot.

Prepulses are characterized by several parameters: their amplitude, width and time interval before the foot of the main pulse. We show that these parameters can be reduced to a single one –the prepulse energy- that makes possible their study in an otherwise huge parameter space.

For one specific target design (sub-MJ with KrF light) with a moderate fuel α(α=4), we show prepulses' effects on gain and 1D stability (Rayleigh-Taylor only) and point out the regime which seems most promising.

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*Work supported by USDOE

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Stabilization Effects of Density Graded Foams on Perturbations Due to Target Imperfections at the Outer Surface

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In our earlier work [1] we introduced the idea that tailored density profiles can be used to reduce the early-time laser-imprinted perturbation growth. In that work we demonstrated that in a target with a tailored density profile the laser-seeded mass perturbation amplitude was significantly reduced for all perturbation wavelengths, compared to a uniform target of the same mass and thickness. We found this to be true in all cases of laser imprint we considered. However, if we consider targets with a rippled outer surface instead of laser imprint, this might not always the be case, particularly in a somewhat more complicated and practically important situation when the stabilizing density gradient in the target is not pre-manufactured but rather produced dynamically by a spike pre-pulse preceding the main driving pulse [2]. The shock launched through a rippled surface is also perturbed [3]. When the perturbed shock moves up the density gradient the corresponding areal mass perturbation tends to grow even if the shock displacement does not. The shock decays asymptotically, but before it starts decaying, it might increase its displacement amplitude several times compared to the initial ripple amplitude [4]. The 1D profiles of density and pressure peak at the shock front, implying a rippled rarefaction wave immediately behind the rippled shock front, which is the main cause of the growth [5]. In this work we distinguish between the perturbation behavior near the outer surface and the perturbation carried into the target by the perturbed shock. We investigate whether a density gradient can be tailored to mitigate the Rayleigh-Taylor seeding via surface imperfections as well as it reduces laser imprint.

Work supported by the U. S. Department of Energy and performed at the Naval Research Laboratory.

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Langmuir Wave Decay Instability for Large $k\lambda_D$

Harvey A. Rose
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Vlasov simulations are presented, which confirm reduction[1] of the linear LDI threshold, due to the trapped electron frequency shift of the parent Langmuir wave (LW). This shift and frequency matching may allow the daughter LW's wavenumber to be much smaller than implied by standard theory's wavenumber shift, $\Delta k\ \lambda_D = (2/3)c_s/v_e$. Yet experimental data[2] reveals this standard shift. A reduced model for the LDI daughter LW must therefore allow amplitude and wavenumber dependent damping, to capture the possibly wide range of Landau damping it is subject to, as well as the trapped electron frequency shift.

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2 J. L. Kline et al., "Observation of a Transition from Fluid to Kinetic Nonlinearities for Langmuir Waves Driven by Stimulated Raman Backscatter", PRL **94**, 175003 (2005).

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Investigation of High Z dopants to Mitigate Stimulated Raman Scattering in Gas Filled Hohlraums

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R. M. Stevenson
Atomic Weapons Establishment, Aldermaston, Reading RG7 4PR, United Kingdom

The successful achievement of thermo-nuclear ignition at the National Ignition Facility (NIF) depends on overcoming several key challenges. One such challenge is that of laser plasma instabilities. Laser plasma instabilities scatter the incident laser light reducing the energy converted to soft x-rays which are then coupled to the ignition capsule. If an insufficient amount of x-ray radiation is not coupled to the capsule, ignition can not take place. One approach to this challenge is to validate theories that show the possibility of mitigating laser plasma instabilities. Building an arsenal of such strategies provides a number of options for ignition designers in the event laser plasma instabilities scatter too much of the incident laser light. One such mitigation strategy is the use of High Z dopants in the hohlraum gas fill.

Gas bag experiments at the Helen laser a few years ago showed that the addition of a small amount of high Z dopant could significantly reduce laser plasma instabilities. More recently, theoretical work at Los Alamos National Laboratory provided a theoretical basis for the reduction in backscattered laser light. Thermal filamentation of the laser results in beam spray that in turn reduces stimulated Raman scattering. Since thermal effects depend strongly on Z^2, a small amount of a high Z dopant can have a large effect. To validate the theory, experiments are currently underway at the Omega laser in NIF relevant plasmas using gas filled hohlraum. Using the 3ω Transmitted Beam Diagnostic developed by Lawrence Livermore National Laboratory, the beam spray, as well as transmitted energy, from an interaction laser beam can be monitor while monitoring the stimulated Raman backscattered light as High Z material is added to the gas fill. In recent Omega experiments, a Xe dopant has been varied in a neopentane gas fill hohlraum. Details of the experiment and the results will be presented.

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Nonlinear Effects on the Saturation of Stimulated Raman Scattering

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

We report on our continued study of the saturation and recurrence of Stimulated Raman Scattering (SRS). We use the fully explicit electromagnetic PIC code OSIRIS. In more strongly driven cases, saturation appears to occur when trapped particles escape their initial bucket rather than executing numerous bounces. Trapped particle effects such as side band instabilities are observed, although they do not appear to be the saturation mechanism for the strongly driven cases. On the other hand, for more weakly driven systems which are the case for NIF, the saturation appears to involve a variety of effects. The interplay and relative roles of nonlinear frequency shifts, sideband production, Doppler shifts due to bulk plasma drift, and kinetic wavebreaking are discussed for a range of plasma parameters ($k\lambda_D \sim 0.26$ to 0.35, $v_{osc}/c \sim 0.007$ to 0.045). Recurrence is dependent on the system's return to a more quiescent state after the plasma waves have saturated and convected away.

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Investigation of Stimulated Raman Scattering Using a Short-Pulse Single-Hot-Spot at the Trident Laser Facility

J. L. Kline, K. Flippo, D. S. Montgomery, R. P. Johnson, T. Shimada, and H. A. Rose
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A new short-pulse version of the single-hot-spot configuration has been implemented to enhance the performance of experiments to understand Stimulated Raman Scattering. The laser pulse length was reduced from ~200 to ~4 ps. The reduced pulse length improves the experiment by minimizing effects such as plasma hydrodynamics and filamentation. In addition, the shortened laser pulses allow full length 2D particle-in-cell simulations of the experiments. Using the improved single-hot-spot configuration, a series of experiments to investigate $k\lambda_D$ scaling of SRS has been performed. Details of the experimental setup and results will be presented.

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Cavity Formation and Collapse in Stimulated Brillouin Scattering*

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

Linear theory of stimulated Brillouin scattering (SBS) predicts higher laser reflectivities than are observed in experiments. Recently, Weber, Riconda, and Tikhonchuk (PRL **94**, 055005 (2005) and Phys. Plasmas **12**, 112107 (2005)) showed that one dimensional particle-in-cell (PIC) simulations of SBS in the strongly coupled regime develop long-lived density cavities after the occurrence of X-type wavebreaking. These density cavities are several laser wavelengths long and are capable of trapping laser energy within them. This poster presents one- and two-dimensional OSIRIS simulation results on strongly coupled SBS. The 1D results are in general agreement with the results of Weber et al.; however the 2D results indicate that in multi-dimensions the cavities exist for shorter times and their collapse strongly heats the plasma. Several runs, each with different densities, indicate that cavity formation does not occur until SBS and diffusion into the surrounding vacuum have lowered the density to around the quarter critical density. These simulations demonstrate that cavity formation is due to strongly coupled, localized Raman scattering that digs a hole in the electron density. This hole allows the laser to become trapped, which further enhances the cavity. Preliminary results from simulations in which the laser propagates up a density gradient will also be presented.

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Kinetic-Ion Simulations and Reduced Models for Stimulated Brillouin Backscattering*

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One and two-dimensional simulations with the BZOHAR[1,2] hybrid code (kinetic PIC ions and Boltzmann fluid electrons) are being used to investigate the saturation of stimulated Brillouin backscatter (SBBS) instability relevant to plasma conditions being actively considered for experiments in the National Ignition Facility. The simulation physics model provides a first-principles description of several nonlinearities that can affect SBBS saturation: ion wave breaking and trapping (and the associated nonlinear frequency shift of the ion wave and nonlinear relaxation of the ion collisionless kinetic dissipation), two-ion-wave-decay instability, harmonic generation, and pump depletion.[1-3] A reduced model that captures the physics of two-ion-wave-decay instability, ion trapping effects (nonlinear frequency shift and reduction of ion Landau damping[3]), and pump depletion has been synthesized leading to coupled-mode equations and a simplified dynamic model of ion trapping that are being implemented in the pF3d fluid simulation code.[4] pF3d includes laser-beam structure, a self-consistent calculation of filamentation, and coupled mode equations for Raman and Brillouin backscatter, and is used for macroscopic 2D and 3D simulations of laser-plasma interactions in space-time domains that are generally much larger than those that can be addressed with kinetic simulations.

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*This work was performed under the auspices of the U.S. Dept. of Energy by the University of California Lawrence Livermore National Laboratory under contract No. W-7405-ENG-48.

Wednesday, June 7, 2006

9:00 -	10:00 AM	Invited Talk – M. Marinak Session Chair: S. Craxton
10:00 -	10:40 AM	Oral Session 5
10:40 -	11:00 AM	Coffee Break
11:00 -	12:20 PM	Oral Session 6 Session Chair: S. Craxton
12:30 -	1:30 PM	Lunch
1:30 -	3:00 PM	Focus Group Hydrodynamic Simulations and Experiments Discussions
5:45 -	6:30 PM	Reception
7:00 -	10:00 PM	Banquet – Bar J Chuckwagon

Morning Invited Talk 3

Speaker: M. Marinak
9:00 am – 10:00 am

Session Chair: Stephen Craxton,
University of Rochester LLE

36th Annual Anomalous Absorption Conference
Jackson Hole, Wyoming, USA
June 4-9, 2006

New Capabilities for Simulations of Radiation Hydrodynamics and Challenges for the Future*

M. M. Marinak,
N. R. Barton, R. Becker, D. H. Munro, S. W. Haan
Lawrence Livermore National Laboratory

The design of inertial confinement fusion experiments and interpretation of the experimental results rely heavily upon complex codes which treat a full spectrum of physical processes. The variety of experiments they are used to simulate continues to expand. We consider relatively new categories of simulations facilitated by recent advances in the 2D/3D multiphysics code HYDRA. One class of simulations examines effects induced by the polycrystalline structure of the beryllium ablator in a NIF ignition capsule. In one proposed design a silicon foam-filled hohlraum generates high levels of x-ray preheat, causing the beryllium grains to expand into the ice. To examine the effect on the capsule a 3D polycrystalline model is employed that resolves the anisotropic elastic and plastic response, down to individual grains. HYDRA simulations resolve the subsequent growth of perturbations seeded in this capsule for modes ranging up to $l \sim 1800$. A second category of interest encompasses well-resolved simulations of engineered features in targets. As an example we consider a NIF hohlraum with a line of sight pipe attached to a mock capsule. The view through the pipe enables precise, direct measurement of the timing of shocks transiting the shell. This experimental geometry will be employed to tune the timing of staged shocks in NIF ignition capsules. Direct simulations can assess how closely the timing information obtained from this surrogate target matches the ignition capsule. Our discussion will also cover capabilities planned for the future. These include modeling of magnetic fields in 3D, including the complications that arise from wide variations in the Hall parameter and from the Nernst convective term. Outstanding issues comprising challenges for the future will also be discussed.

*This work performed under the auspices of the U. S. Department of Energy by the University of California Lawrence Livermore National Laboratory under Contract No. W-7405-ENG-48.

Oral Session 5

10:00 am – 10:40 am

Session Chair: Stephen Craxton,
University of Rochester LLE

36th Annual Anomalous Absorption Conference
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Thoughts on the Modeling of Fluid Instabilities in Inertial Confinement Fusion Hydrodynamics Codes*

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The problem we which to address is that of accurately modeling the evolution of small-amplitude perturbations to a time-dependent flow, where the unperturbed flow itself exhibits large-amplitude temporal and spatial variations. In particular, we wish to accurately model the evolution of small-amplitude perturbations to an imploding ICF pellet, which is subject to both Richtmyer-Meshkov and Rayleigh-Taylor instabilities.

Any errors that we make in numerically modeling the unperturbed flow, if they have a projection onto the space of the perturbations of interest, can easily compromise the accuracy of those perturbations, even if the errors are small relative to the unperturbed solution. As we have reported recently, most of the progress we have made toward our goal of accurately modeling the evolution of such small-amplitude perturbations has been achieved by imposing a "differentiability condition" on the individual numerical components of our radiation hydrodynamics codes.

Here we give an update on that work, and modify our previous numerical design criteria to include the notion of "effective nondifferentiability."

* This work was supported by the U.S. Department of Energy

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Prospects for achieving double-shell ignition on the National Ignition Facility using vacuum hohlraums

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The goal of demonstrating ignition on the National Ignition Facility (NIF) has motivated a revisit of double-shell (DS) targets [1] as a complementary path to the cryogenic baseline approach [2]. Benefits of DS ignition targets include non-cryogenic deuterium-tritium (DT) fuel preparation, minimal hohlraum-plasma mediated laser backscatter, low threshold-ignition temperatures ($\approx$ 4 keV) for relaxed hohlraum x-ray flux asymmetry tolerances [3], and minimal (two-) shock timing requirements. On the other hand, DS ignition presents several formidable challenges, encompassing room-temperature containment of high-pressure DT ($\approx$ 800 atm) in the inner shell; strict concentricity requirements on the two shells (< 3 μm); development of nanoporous (<100 nm), low-density (<100 mg/cc), metallic foams for structural support of the inner shell and hydrodynamic instability mitigation; and effective control of hydrodynamic instabilities on the high-Atwood number interface between the DT fuel and the high-Z inner shell.

Recent progress in DS ignition designs using vacuum hohlraums are described. New high-yield designs are presented that utilize 2 MJ of laser energy at 3ω delivered over 4.5-5.5 ns. In the absence of hohlraum low-Z gasfills, liners, windows and anti-convection baffles, less laser-plasma mediated backscatter is anticipated. Calculations with the Laser Plasma Interaction (LIP) [4] postprocessor suggest maximum gain-length products less than eleven are expected for all laser cones. The outermost cone at 50° has the highest predicted backscatter in SBS due to the intervening wall cocktail material near the lip of the laser entrance hole.

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*This work was performed under the auspices of U.S. Department of Energy by the Lawrence Livermore National Laboratory under Contract No. W-7405-Eng-48.

Oral Session 6

11:00 am – 12:20 pm

Session Chair: Stephen Craxton,
University of Rochester LLE

36th Annual Anomalous Absorption Conference
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Performance and Stability of Sub-MJ Direct-Drive Pellets*

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3LCP&FD, Naval Research Laboratory, Washington DC

There is interest in producing appreciable fusion yield with lasers that are as small as possible. Targets with yields of order 10MJ, when ignited at several Hz, can form the basis of a facility useful for fusion testing[1]. We find that useful targets can be designed for laser energies of significantly less than a megajoule, and extensively analyze targets driven by about 500 kJ. In order to produce igniting pellets in this energy range, the implosion velocity must be increased to ~4x107cm/s. Likewise, in order that the hydrodynamic stability be minimized, the drive pressure must also increase. The laser that best handles these demands is the KrF laser, with its inherent optical smoothing ability and short wavelength (0.248 microns). The short wavelength allows penetration to higher densities (producing higher pressure) while minimizing the risk of laser-plasma instability.

Targets designed using this approach will be presented here. We will show both 1D and 2D simulation results and analysis. We employ recently developed numerical algorithms[2] and modern strategies that optimize both the gain and stability[3]. The sensitivity of these targets to both low-mode (e.g., beam geometry, power imbalance, surface finish) and high mode (pellet uniformity, laser imprint) sources is examined. We find that targets resistant to hydrodynamic instabilities can produce substantial gain while being driven by ~500 kJ of KrF light.

[1] S. P. Obenschain *et al.*, to be published in Phys. Plasmas (2006).
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N. Metzler, A. Velikovich, and J. Gardner, Phys. Plasmas **6**, 3283 (1999);
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* *Work supported by US DOE*

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An Update on Polar-Direct-Drive Experiments on OMEGA

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Polar-direct-drive (PDD) experiments[1–3] have continued on OMEGA using both "standard-PDD"[4] and Saturn targets[5] with a view to approaching ignition on the NIF using just the baseline indirect-drive ports with the beams repointed toward the equator. Most experiments have used Saturn targets, which include a low-*Z* ring around the capsule and have been found to give yields close to those of targets irradiated symmetrically with an equivalent energy.

Recent experiments have shown that both types of PDD target are relatively insensitive to modest changes in the beam pointings and, in the case of Saturn targets, the major radius of the ring. The demonstrated pointing accuracy on OMEGA is significantly better than that required to tune a PDD target. Other factors such as the target mounting scheme (e.g., spider silk versus spokes), the method by which the Saturn ring is fabricated, and the thickness of the Al gas retention barrier on the capsule have been investigated.

Using the most symmetric Saturn configuration, experiments have also been carried out in which the backlighter is optimized to probe the imploded core. This has made it possible to explore the difference between targets imploded with and without SSD beam smoothing. Preliminary results show that 1-THz, two-dimensional SSD results in a better-formed implosion core.

This work was supported by the U.S. Department of Energy Office of Inertial Confinement Fusion under Cooperative Agreement No. DE-FC52-92SF19460, the University of Rochester, and the New York State Energy Research and Development Authority. The support of DOE does not constitute an endorsement by DOE of the views expressed in this article.

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A Monoenergetic Proton Backlighter for Measuring E and B Fields and for Radiographing Implosions and HED Plasmas

R ch
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R. P. Town, P. A. Amendt, S. P. Hatchett, O. L. Landen, A. J. Mackinnon, P. K. Patel
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A novel monoenergetic proton backlighter source has been utilized at OMEGA to study electric (E) and magnetic (B) fields generated by laser-plasma interactions, and will be utilized in the future to radiograph OMEGA implosions. Such a backlighter consists of an imploding glass micro-balloon with D_3He fuel directly driven by 20 or fewer beams. D_3He reactions generate penetrating 14.7 MeV protons, and DD reactions generate 3.0 MeV protons. For quantitative study of E+B field structure, monoenergetic protons have several unique advantages compared to the broad energy spectrum used in previous experiments. To this point, in recent experiments with a single laser beam (intensity ~ 10^{14} W/cm^2) interacting with a CH foil, B fields of ~ 0.5 MG and E fields of ~2×10^8 V/m have been measured using proton deflectometry. LASNEX simulations are being used to simulate these experiments. Additional information will also be presented on the application of this technique to measuring E and B fields associated with hohlraums and directly driven implosions, and to radiographically mapping the areal density (ρR) distribution in imploded capsules, and to radiographing high-energy density (HED) plasmas.

The work described here was performed in part at the LLE National Laser User's Facility (NLUF), and was supported in part by US DOE (Grant No. DE-FG03-03SF22691), LLNL (subcontract Grant No. B504974), and LLE (subcontract Grant No. 412160-001G).

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Measuring E and B Fields in Laser-Produced Plasmas Through Monoenergetic Proton Radiography

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Electromagnetic (E/B) fields generated by the interaction with plasmas of long-pulse, low-intensity laser beams relevant to inertial confinement fusion have been measured, for the first time, using novel monoenergetic proton radiography methods. High-resolution, time-gated radiography images of a plastic foil driven by a 10^{14} W/cm^2 laser implied B fields of ~ 0.5 MG and E fields of ~ 1.5×10^8 V/m. Complete simulations of these experiments with LASNEX+LSP have been performed and are quantitatively consistent with the data both for field strengths and for spatial distributions; this is the first direct experimental test of the B-field generation package in LASNEX. The experiments also demonstrated that laser phase plates substantially reduce small-scale chaotic field structure.

The work described here was performed in part at the LLE National Laser User's Facility (NLUF), and was supported in part by US DOE (Grant No. DE-FG03-03SF22691), LLNL (subcontract Grant No. B504974), and LLE (subcontract Grant No. 412160-001G).

Thursday, June 8, 2006

9:00 -	10:00 AM	Invited Talk – N. Meezan Session Chair: L. Divol
10:00 -	10:40 AM	Oral Session 7
10:40 -	11:00 AM	Coffee Break
11:00 -	12:20 PM	Oral Session 8 Session Chair: L. Divol
12:30 -	1:30 PM	Lunch
7:00 -	8:00 PM	Invited Talk – B. Albright Session Chair: F. Tsung
8:00 -	11:00 PM	Poster Session

Morning Invited Talk 4

Speaker: N. Meezan
10:00 am – 10:00 am

Session Chair: Laurent Divol,
Lawrence Livermore National Laboratory

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Progress and Challenges in Hydrodynamics Simulations for Laser-Plasma Interaction Predictive Capability†

N. B. Meezan, R. L. Berger, L. Divol, D. H. Froula, D. E. Hinkel, O. S. Jones, C. Niemann*, S. T. Prisbrey, E. A. Williams, S. H. Glenzer, and L. J. Suter
Lawrence Livermore National Laboratory, Livermore, CA USA 94550

This talk presents the current methodology for LPI analysis of hohlraum experiments, i.e., LPI "post-dictive" capability, and discusses key physics obstacles to true LPI predictive capability. This methodology is based on radiation-hydrodynamics simulations that capture the wide range of bulk plasma conditions that exist in the experiments. By applying linear-gain post-processing analysis to these simulations, we find that we can explain the measured backscatter and laser transmission in many NIF-like plasmas. This supports an "Occam's Razor" approach to LPI evaluation of hohlraum targets: nonlinear physics is not introduced unless linear theory is insufficient to explain the results. Recent experiments provide evidence that our simulations accurately predict the plasma conditions in our target platforms. We find that subtle features in the measured backscatter spectra are often caused by bulk hydrodynamic phenomena rather than by speckle-scale LPI phenomena. In Raman-producing gas targets, we can reproduce backscatter streak spectra from the simulated density and temperature changes in the bulk plasma. The transmitted light in hohlraum targets is shifted in wavelength due to the rapidly changing density in the interaction-beam channel. When we correct the Brillouin gain spectra for this shift, they agree well with the measured spectra. Furthermore, we find that the measured backscatter increases monotonically with the linear gain and that filamentation occurs at the predicted linear threshold. These results confirm the utility of linear gain as a metric for LPI risk.

Despite the success of linear physics in explaining LPI experiments, obstacles remain to developing true predictive capability. Nonlinear LPI phenomena such as the Langmuir decay instability and ion-trapping in acoustic waves have been directly observed in small laser facilities, but they are not needed to explain many NIF-relevant experiments. Designing experiments to detect nonlinear phenomena in NIF-like plasmas remains a great challenge for the laser-plasma community. This will require careful tuning of plasma conditions, which in turn will require better simulations and experimental validation of those simulations. Ultimately, a better understanding of linear and nonlinear LPI physics, by leading to new, more effective methods for reducing LPI in ignition hohlraums, may be the key to achieving ignition on NIF.

† This work was performed under the auspices of the U.S. Department of Energy by the University of
California Lawrence Livermore National Laboratory under contract No. W-7405-ENG-48.
* Currently at University of California Los Angeles

Oral Session 7

10:00 am – 10:40 am

Session Chair: Laurent Divol,
Lawrence Livermore National Laboratory

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Modeling Parametric Scattering Instabilities in Large-Scale Expanding Plasmas

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One of the main obstacles to achieve reliable modeling of parametric instabilities in fusion-relevant plasmas is the variety of the spatial and temporal scales involved. The usual description of laser light propagation in expanding plasmas, relying on a spatial resolution at the order of the laser wave length, is inadequate to take into account for parametric backscattering instabilities.[1] Recent experiments at Mega-Joule laser conditions clearly demonstrate the presence of Stimulated Brillouin Scattering (SBS) and Stimulated Raman Scattering (SRS) and underline the difficulty to suppress these processes at parameters relevant to laser fusion.

To describe the scattering instabilities, in a first step SBS, with the goal of future predictive modeling in an expanding mm-scale plasma, we have developed a numerical code which makes use of the decomposition of spatial scales [2] : while one can use a conventional hydrodynamics code for the long-scale length plasma expansion, the short-wavelength plasma waves excited by the scattering instabilities are described by paraxial envelope equations, similar to the code pF3d [3]. We have benchmarked our decomposition code "Harmony" for the case of SBS against a "complete" code without decomposition, neither in hydrodynamics nor in the electromagnetic field.

We also show a comparison between 2D simulations and recent LULI experiments with smoothed and single speckle laser beams of an expanding mm-size plasma in which we find that a non-negligible fraction of the backscattered light and transmitted laser light is found outside the solid angle cone associated with aperture of the incident laser light [4].

A main difficulty to achieve a complete description of SBS (and of SRS) is the onset of kinetic effects due to the nonlinear plasma waves arising at much shorter time and spatial scales than affordable by macroscopic modeling. We have also performed comparisons between the Harmony code and a particle-in-cell (PIC) code in which we tried to elaborate the parameter regime where phenomenological modeling of weak kinetic effects is possible, based on a nonlinear frequency shift.[5,6] For the modeling in the code Harmony subharmonic generation has been taken into account, which proves to be indispensable.

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[3] R. L. Berger, et al., Phys. Plasmas 5, 4337 (1998).
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[6] L. Divol et al., "A reduced model of kinetic effects related to the saturation of stimulated Brillouin scattering", LLNL report UCRL-JC-155169 (IFSA 2003 proceedings).

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Light Spreading Induced by Stimulated Brillouin Scattering in an Inhomogeneous Flowing Plasma

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By means of numerical simulations, we demonstrate the existence of a new mechanism giving rise to an additional smoothing to the transmitted and SBS-backscattered waves of an incident RPP beam. This mechanism-that we name "SBS induced incoherence", and that we denote as SBSII- is distinct from the so-called plasma induced smoothing. The latter involves the nonlinear propagation of the incident light and takes place only when the laser beam power contained in a single speckle exceeds, in average, the critical power for filamentation. By contrast, SBSII occurs whenever SBS takes place in inhomogeneous flowing plasma.

In order to exemplify the smoothing effect due to SBS, we first carried out simulations in expanding plasma in the extreme limit where all the waves are undamped. Streak diagnostics of the reflected and transmitted light clearly exhibit spatio-temporal incoherence. It follows in particular that the transmitted (SBS-backscattered) light flux collected only within the incident light cone is significantly lower than the transmitted (SBS-backscattered) collected within the full exit (entrance) boundary.

In order to test the robustness of this phenomenon, we then carried out simulations corresponding to realistic laser-plasma interaction experiments with an RPP laser beam interacting with an exploding foil plasma, whose density, velocity and temperatures profiles were imported from the radiative-hydrodynamic code FCI2. We described SBS and self-focusing, taking into account the wave dampings, together with the self-consistent hydrodynamics evolution and plasma heating. Our simulations results confirm the existence of SBSII in realistic laser-plasma interaction experiments, although the scenario becomes complex due to other concomitant effects such as plasma induced smoothing and light absorption. It is typically observed that SBSII and plasma induced smoothing both take place, complementing each other and leading to large aperture angles to the transmitted and the SBS-backscattered beams.

In conclusion, we demonstrated that SBS taking place in multidimensional and inhomogeneous plasma gives rise to a new smoothing mechanism, complementary of plasma induced smoothing. In many experiments carried out in the recent past, large angular widths of the backscattered light were reported. SBSII could be responsible for this feature, and hence could explain the frequent discrepancy between theory and experiments concerning the SBS reflectivity whenever the latter is measured within the incident light cone only.

Oral Session 8

11:00 am – 12:20 pm

Session Chair: Laurent Divol,
Lawrence Livermore National Laboratory

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Vlasov Simulations of Kinetically-Enhanced Raman Backscatter, and Electron Acoustic Thomson Scattering

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Recent experiments[1,2] PIC simulations[3,4] show enhanced stimulated Raman backscatter (SRBS) in regimes where the daughter plasma wave is heavily Landau damped. Accompanying strong SRBS, experiments report reflected light at a frequency between that of the laser and SRBS. This has previously been interpreted as stimulated electron acoustic scattering (SEAS)[2,5], or laser scattering by an undamped electron acoustic wave (EAW) supported by trapped electrons at the EAW phase velocity. We present 1-D Eulerian Vlasov-Maxwell simulations with the ELVIS code which exhibit both kinetically-enhanced SRBS and reflected light similar to SEAS[6,7]. We demonstrate this light is produced by electron acoustic Thomson scattering (EATS), the Thomson-like scattering off EAW fluctuations resulting from a new parametric decay of the nonlinearly shifted SRBS plasmon.

The observed electrostatic dynamics differ from the linear plasma waves of a Maxwellian distribution. The simulation (k,ω) spectrum reveals the plasma wave splits into two branches, one of which is acoustic ($\omega \propto k$) for low k and frequency-downshifted from the linear plasma wave for larger k. This resembles the beam acoustic mode (BAM) of Yin[3], and SRBS occurs off this branch. A much weaker EAW with $\omega \sim 1.2kv_{Te}$ also develops. The electrostatic (k,ω) that phase-matches the observed SEAS-like light lies on the EAW curve, although most EAW activity is at much lower frequency. The low noise in our Vlasov code allows resolution of such weak signals.

We find the complex, linear modes of the numerical distribution during strong SRBS by projecting it onto a Hermite basis, and computing the susceptibility via the associated sums of Z (plasma dispersion) functions. Modes corresponding to the two plasma-wave branches (including the BAM) and the EAW are present. The BAM is less damped than the Maxwellian plasma wave at the same k.

The EAW at low k is energized by beam acoustic decay (BAD), i.e. the parametric decay of the Raman BAM to a lower-frequency point on the same BAM curve and an EAW. The daughter EAWs thus produced are much too low in frequency to scatter the pump, but weakly excite the EAW curve at higher ω by harmonic generation. This enhanced EAW noise then produces SEAS-like light via Thomson scattering (EATS). Third-order spectral analysis (bispectrum and bicoherence) supports the parametric nature of the BAD and EATS processes.

Work at LLNL performed under the auspices of the U.S. Department of Energy by University of California, LLNL under Contract W-7405-Eng-48.

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[3] L. Yin et al., *Phys. Rev. E* **73**, 025401 (2006)
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Implications of the Trapping-Inflation Scenario for SRS

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The 1D RPIC simulations (see Vu *et al.* previous talk) can be regarded as completely characterized numerical experiments whose kinetic theory can be worked out in detail (see Bezzerides *et al.* previous talk). The successful comparison of this theory of the inflation threshold with the 1D simulations suggests a natural generalization of the theory to 3D laser-plasmas. The diffusion criterion for trapping, verified in 1D, when applied to 3D is exactly the criterion found in the seminal work of Zakharov and Karpman (Sov. Phys. JETP,16, 351 (1963)) for trapping to reduce the LW damping, below Landau damping levels, in the presence of electron-electron collisions. Estimates of the inflation thresholds for 3D single hot spots can be made for NIF conditions. The 1D simulations show that for intense NIF hot spots, the reflectivity is a smooth, monotonically decreasing, function of $k_1\lambda_D$ out to $k_1\lambda_D \sim 0.8$ (where k_1 is the wavenumber of the primary Langmuir wave), since there is a coupled parametric resonance even in the strongly damped "Compton" regime. Furthermore the inflation of SRS in such regimes, above linear convective values, is still seen. When the computed SRS reflectivity, as a function of hot spot laser intensity, is used in an independent hot spot, statistical, model, a rapid jump in the reflectivity, with increasing averaged laser intensity, is seen to be controlled by the inflation threshold. Since the inflation threshold is expressed in terms of the local amplitude of the Langmuir wave this physics can be readily included in a nonlinear propagation code such as pf3d (see poster by Evan Dodd at this conference). As a preliminary surrogate for pf3d the inflation threshold can be used in a 1D, three-wave envelope model, to turn on the trapping nonlinearities -the reduced damping and frequency shift- and compared to the RPIC simulations.

Research was performed under the auspices of the DOE/NNSA by LANL under contract W-7405-ENG-26. H.X. Vu is supported by the NNSA under the Stewardship Science Academic Alliances Program through DOE Research Grant# DE-FG52-04NA00141/A000.

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RPIC Simulations as Experiments: Developing a Comprehensive Model of Raman Inflation

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The rapid onset and steep rise of backward stimulated Raman scattering in single laser hotspot as a function of increased laser intensity was first predicted by RPIC simulation [Vu *et al.*, Phys. Plasmas **9**, 1745 (2002)], and experimentally confirmed [Montgomery *et al.*, Phys. Plasmas **9**, 2311 (2002)]. The onset threshold was identified as due to electron trapping and the associated reduction of Landau damping of the daughter Langmuir wave. We have employed the RPIC code as an experimental platform to obtain a detailed understanding of the physical mechanisms controlling the reflectivity below, on, and above the onset threshold, designated as the foot, cliff, plateau, respectively. In this talk we compare analytical calculations with the results of these experiments in the foot region. We find that in the foot region linear convection is a complete description of the saturated state. To obtain detailed agreement it is essential to account for the shape of the hotspot intensity, the linear damping of the Langmuir wave due to sideloss resulting from electrons transiting across the axial extent of the hotspot, and use of the correct Langmuir noise spectrum appropriate to a 1D particle simulation. The kinetic theory of the side loss damping of the Langmuir wave is validated by direct simulation. This agreement with the analytic linear amplification results is important, since given the nonlinear condition for trapping in terms of the Langmuir wave amplitude the linear theory of the convective amplification of the Langmuir wave can be used to convert this condition to one involving the peak laser hot spot intensity.

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A Threshold for Superlinear Enhancement of Stimulated Raman Scattering by Electron Trapping

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The rapid onset, with increasing laser intensity, of levels of backward stimulated Raman scattering (BSRS) exceeding linear convective predictions, from single laser hot spots has been observed [Montgomery *et al.*, Phys. Plasmas **9**, 2311 (2002)], and is predicted by simulations [Vu *et al.*, Phys. Plasmas **9**, 1745 (2002)], in nonlinear regimes dominated by electron trapping. A theory for this *inflation threshold* is given here. The threshold is the result of competition between velocity diffusion and trapping, and is exceeded when the convectively amplified SRS Langmuir wave (LW) achieves an amplitude for which the coherent trapping velocity increment of electrons in the LW (the half width of the trapping separatrix) exceeds the root-mean-squared (rms) diffusion velocity(resulting from background plasma fluctuations), accumulated in one bounce time, for electrons with mean velocities near the phase velocity of the LW. The results of this theory, when the kinetic theory of the one-dimensional (1D) reduced-description particle-in cell (RPIC) simulation is used, are in good agreement with a series of 1D RPIC simulations. Comparison of the LW trapping-induced inflation threshold to the LW threshold for the Langmuir decay instability provides an estimate for the transition between the nonlinear saturation regimes where LDI dominates and where trapping dominates. Phase space diagnostics verify that electron trapping occurs only above the inflation threshold whereas linear, convective saturation describes the behavior below the threshold (see the following talk by B. Bezzerides *et al*). The theory is naturally generalized to three dimensions (see the following talk by D.F. DuBois, *et al* at this conference), and is compatible with macroscopic laser interaction codes such as pf3d [Berger *et al.*, Phys. Plasmas **5**, 4337 (1998)]. The single hot spot inflation threshold also controls the sharp rise in the reflectivity in an independent hot spot statistical model.

Research was performed under the auspices of the DOE/NNSA by LANL under contract W-7405-ENG-26. H.X. Vu is supported by the NNSA under the Stewardship Science Academic Alliances Program through DOE Research Grant# DE-FG52-04NA00141/A000.

Evening Invited Talk 3

Speaker: B. Albright
7:00 pm – 8:00 pm

Session Chair: Frank Tsung,
University of California, Los Angeles

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Kinetic Plasma Simulation Tools and Outlook*

B. J. Albright
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Numerical simulation of the interaction of high power lasers with underdense and overdense media is challenging because of the rich dynamics that manifest on a wide range of length and time scales. For instance, NIF laser beams will propagate into gasfilled hohlraums over distances of millimeters, yet their interaction with underdense plasma can lead, in many settings, to the emergence of complex wave-particle dynamics occurring on Debye-length scales (which are several orders of magnitude smaller). Similarly, in the interaction of short pulse lasers with solid density targets, as envisioned for fast ignition ICF scenarios, processes such as resistive and collisionless filamentation of electron beams, sheath formation, self-magnetic field generation, and electron and ion propagation in target material, can involve length scales from Angstroms to millimeters and time scales from attoseconds to tens of picoseconds. Currently, no one simulation tool is capable of modeling these systems in their entirety at all length and time scales of interest. Therefore, a hierarchy of kinetic plasma simulation models of varying degrees of approximation has been developed. These range from Vlasov and explicit particle-in-cell techniques, which resolve the smallest scales, to more reduced models, such as implicit and hybrid methods. In this talk, several of these techniques will be reviewed, their relative strengths and conditions of applicability will be compared, and challenges to their validation will be examined. Some speculation will be offered on possibilities for the future enabled by advances in computing (e.g., petascale platforms).

*This work was performed under the auspices of the U.S. Department of Energy (DOE) by the University of California
Los Alamos National Laboratory under contract W-7405-ENG-36.

Poster Session 3

8:00 pm – 11:00 pm

Session Chair: Frank Tsung,
University of California, Los Angeles

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Transverse Field Compression and Harmonics in Light from P-Polarized Laser Pulses Obliquely Incident on Thick Overdense Plasmas with Steep Gradients

Tudor Johnston, Yuri Tyshetskiy, Ljubomir Nikolic and François Vidal
INRS-EMT, Varennes, QC, CANADA

With a view to experiments planned for the ALLS 200 TW 24 fs laser (coming online in the autumn of 2006), 2D simulations have been done with the OSIRIS code*. The earliest results resemble those of Naumova et al. (PRL). Within the framework of the code we have developed various diagnostics (used as input to MatLab) designed to make plain the basic physics going into the creation of the remarkable waveforms seen. The basic object of this is the optimization of the reflected light output for various experiments. The relationship of these results to others will be discussed, in particular the various results obtained by others with the 1.5 D "Bourdier-Gibbons" PIC model and the "sliding mirror" concepts and results of Pirozhkov, Bulanov et al. (Phys. Plasma 13, 013107 (2006)).

* The OSIRIS code was made available to us by Warren Mori of UCLA.

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The Krook Collision Model as a Template for Calculating Electron Thermal Flux in Laser Produced Plasmas

W. Manheimer, *R.S.I. (Consultant to NRL),* **D. Colombant**, *NRL,* **V. Goncharov**, *LLE, University of Rochester*

This paper explores what appears to be a new and promising model for electron energy transport in laser produced plasmas, a Krook model for electron electron collisions. Electron energy transport has been a perplexing dilemma in laser fusion. In many regions of the plasma, the mean free path of the current carrying electrons is comparable or larger than the temperature gradient scale length, invalidating a pure fluid model at these points in space. For more than 30 years now, this has been handled with an ad hoc flux limit. During this time, there has been no first principles derivation of such a flux limit. Another approach has been direct Fokker Planck simulations. Such calculations have been performed for 25 years now, but these have generally not found their way into laser fusion fluid simulations for two reasons. First they are extremely time consuming, adding at least one additional dependent variable and forcing a time dependent calculation to the electron instead of the ion time scale. Second, it is not usually clear just how to couple the Fokker Planck simulation to the overall fluid simulation, particularly in the regions of cool dense plasma. Also there have been a variety of ad hoc convolution treatments. These also have not generally found their way into laser plasma fluid simulations, in part because of their lack of genuine justification, in part because they often involve numerical difficulties.

A Krook model treats the electron electron collision operator as $-\nu(f-f_{max})$. It is particularly simple in that it involves no velocity derivatives and can be treated as a steady state problem on the ion fluid time scale. In fact in some cases, one can calculate analytically steady state solutions in the nonlocal limit. However this formulation is also inherently problematical in that if ν depends on particle velocity, it is not necessarily particle or energy conserving. However using it to compute only energy flux does maintain the overall conservative nature of the fluid simulation. In some ways a Krook model may even be more accurate than a Fokker Planck simulation because of the rather small values of the Coulomb logarithm over large regions of the plasma. This paper will present analytic and numerical aspects of our recent investigation of the Krook model.

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Simulations for Gas-filled Hohlraums for LPI Experiments at Omega

S. R. Goldman[1], E. S. Dodd[1], J. L. Kline[1], D. S. Montgomery[1], H. A. Rose[1], and O. S. Jones[2]

Lasnex simulations have been performed using a variety of gas-fills for a fixed hohlraum geometry at the Omega laser. The cylindrical hohlraums, with gold wall thicknesses of 8μm, have axial lengths of 2mm, inner diameters of 1.6mm, and LEH's with diameters of 0.8mm covered by polyimide windows of thickness 0.25μm. The hohlraums are heated by 3ω beams located on three pairs of cones, each nominally symmetric with respect to the hohlraum midplane, making an angle of 21°, 42°, or 58° with the hohlraum axis. A 3ω probe beam along the hohlraum axis, which removes the nominal midplane symmetry, is also included. The simulation technique is benchmarked against previous Thomson scattering results in the same geometry for electron and ion temperatures using an axially-directed 4ω probe beam[3].

The instability theory of collective forward stimulated Brillouin scatter (CFSBS) as a mechanism for beam spray[4] predicts that the onset laser intensity for instability decreases with decreasing ν_{ia}, the normalized ion-acoustic damping frequency at the speckle wavelength, and increasing Z*, the ratio of the mean squared ion charge to the mean ion charge. A direct test of the theory would involve determining the onset intensity for fixed gas fill by varying the probe beam intensity, simultaneously accounting for changes in ν_{ia} and Z*, but this is limited by the energy available for the probe beam. An alternate test involves measurement of backscatter and beam spray over a sequence of gas fill variation at fixed probe beam intensity, with simultaneous observation of ν_{ia}, and Z* at the transition to beam spray. Using conventional Lasnex post-processing as well as the LIP laser plasma interaction post-processor[5], we have obtained estimates of ν_{ia}, Z*, and the gain factors for Raman and Brillouin backscatter over the following sequences of gas-fills (gas amounts in mole fractions):

1. $\alpha*(25\%CH_4/75\%C_3H_8)+(1-\alpha)*(CO_2)$, $0 \leq \alpha \leq 1$ (same charge density at full ionization from gas originally at STP; decreasing ν_{ia}, increasing Z* with increasing α),
2. $\alpha*(C_5H_{12})+ (1-\alpha)*(CF_4)$, (same charge density at full ionization from gas originally at STP; decreasing ν_{ia}, increasing Z* with increasing α),
3. $25\%CH_4/75\%C_3H_8 \rightarrow 25\%CH_4/71\%C_3H_8/4\%Xe$ (slight increase in density at full ionization from gas originally at STP, slight decrease in ν_{ia}, significant increase in Z*).

This provides guidance for specific shots to probe the instability and its consequences.

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[1] Los Alamos National Laboratory
[2] Lawrence Livermore National Laboratory
[3] D. H. Froula, J. S. Ross, L. Divol, N. Meezan, A. J. MacKinnon, R. Wallace, and S.H. Glenzer, to be published in Physics of Plasmas (2006).
[4] P. M. Lushnikov and H. A. Rose, Phys. Rev. Lett. **92** 255003 (2004), P. M. Lushnikov and H. A. Rose, submitted for publication (2006).
[5] R. L. Berger, E. A. Williams, and A. Simon, Phys. Fluids B **1** 414 (1989).

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Evaluation of effects of bonding joint in machined capsules on ignition at the National Ignition Facility (NIF)

James H Cooley and Doug Wilson
Los Alamos National Laboratory, Los Alamos, NM

The current point design for ignition capsules to be fielded at NIF is a beryllium capsule with a graded copper dopant made by a sputtering process. Although this fabrication process has been and continues to improve there is still a desire to provide an alternative capsule, should the sputtering process fail to meet all the specified requirements. To this end, capsules made with uniformed copper dopant and by a machining process are still a viable alternative to those made with sputtering. These capsules are made as two hemispheres and then bonded together with a small weld joint. However, one major risk for the viability of these machined capsules is the effect of this joint on the ignition performance of these capsules.

To mitigate the expected effect of these joints on ignition the National Ignition Campaign (NIC), last year, specified that these joints would be 0.1 mm wide and only penetrate 1/3 of the ablator shell. These specifications were chosen for two reasons, the target fabrication was feasible, although at the very limit of expected capabilities, and the limited calculations we had performed to date indicated that with this specification we should not affect ignition. In this paper, we present further simulations using the code HYDRA, which help bound the requirements for the fabrication of this joint. These calculations further enhance our confidence that a machined capsule with a joint as specified is a viable alternative to the sputtered capsule, should an alternative design be required.

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Outer Beam Focal Spots for the 2009 and 2010 NIF Ignition Experiments*

L. Suter, D. Callahan, D. Hinkel, P. Wegner, S. Pollaine, N. Meezan, O. Landen, J. Lindl, S.Dixit, L. Divol, E. Williams, J. Edwards, B. Langdon
Lawrence Livermore National Laboratory
P. Bradley, E. Dodd
Los Alamos National Laboratory

The National Ignition Facility (NIF) is a 192 beam, 1.8MJ, 500TW laser being constructed at Lawrence Livermore Laboratory to achieve both indirect and direct drive inertial confinement fusion. The NIF schedule calls for us to perform ignition tuning experiments in 2009 followed by the first indirect drive ignition experiments in 2010. To meet that schedule we will have chosen, on June 1 of this year, a design for the 50 and 44.5 degree beams' phase that will be used on the first ignition tuning experiments. These phase plates will determine the focal spots of the128 beams on those two cones. A decision on the remaining 64 phase plates/focal spots for the 30 and 23.5 degree beams is required March 31, 2007.

Although the first, 2009 and early 2010 ignition tuning experiments will be reduced scale (~0.7 of the 2010 ignition target) the design of the focal spot "flows down" from the full scale ignition point design hohlraum. This paper summarizes the work of a large design team that has concentrated on producing an integrated design for hohlraum, focal spots and laser that meets the requirements for ignition. It includes

1. The requirements for the focal spot
2. A brief summary of the great-tradeoff that affects the focal spot decision: radiation-hydrodynamic design flexibility and laser performance vs. laser plasma interactions (LPI).
3. The updated point design hohlraum for the full scale 2010 experiments that has resulted from the work of this integrated team
4. Point design, full-scale focal spot for the 50 and 44.5 degree beams
5. Assessment of laser plasma interactions in the full-scale target with those focal spots
6. Assessment of laser performance with those focal spots for various amounts of SSD bandwidth
7. Assessment of the ability to control 2D and 3D asymmetries with those focal spots
8. Specifications for the reduced scale phase plates that we will be building

*This work was performed under the auspices of the U. S. Department of Energy by the Lawrence Livermore National Laboratory under contract number No. W-7405-ENG-48.

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Calculations of Foam Filled NIF Ignition Hohlraum at 1 MJ Laser Energy

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Preliminary results of a 2-D design study are presented for a SiO2 foam filled hohlraum containing a Cu-doped Be ignition capsule. The hohlraum wall consists of a Au-U "cocktail" designed to maximize the amount of x-ray energy for the capsule to absorb, given the 1 MJ laser energy into the hohlraum. The foam fill acts to minimize wall expansion while maintaining symmetric drive on the capsule. Various foam densities and laser pointings for most efficient drive are considered. Several successful designs are presented along with simulated x-ray and neutron diagnostic images. This work was performed under the auspices of the U.S. Department of Energy by the Los Alamos National Laboratory, under Contract No. W-7405-Eng-36.

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Experimental Studies of Laser Plasma Instabilities at the Nike Laser

J. Weaver[a], J. Oh[b], J. Seely[c], U. Feldman[d], C. Brown[c], G. Holland[e], S. Obenschain[a], B. Afeyan[f], A. N. Mostovych[g], R. H. Lehmberg[a], A. Fielding[h], C. Manka[b], D. Kehne[a], J. Bates[a], A. J. Schmitt[a], L. Phillips[i], L-Y. Chan[a]

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Recent simulations at NRL have shown that high velocity implosions may achieve significant gain at sub-MJ laser energies. These designs are a key element of the development program for the Fusion Test Facility (FTF).[1] The reduction in laser energy is possible, in part, by the application of high intensity laser pulses ($I_{<ave>} > 10^{15}$ W/cm^2). At high intensities, laser-plasma instabilities (LPI) - particularly two-plasmon decay - may play a critical role in limiting the design space for FTF implosions. An issue to be characterized experimentally is the generation of hot electrons by LPI that could create deleterious heating of the pellet. Because the NRL KrF systems are distinguished by operation in the deep UV (248 nm) with broad bandwidth (> 3 THz) and beam smoothing by Induced Spatial Incoherence (ISI), these experiments need to explore conditions that are not easily reproduced at other facilities. Ongoing efforts at the Nike laser facility are examining the two-plasmon decay instability and stimulated Raman scattering. Initial attempts to observe $3/2\omega_0$ emission showed that this instability did not occur for typical Nike operation ($I_{<ave>} \sim 10^{14}$ W/cm^2).[2] This poster will present an overview of this program, including new spectrometers and photodetectors, new targets, increases in Nike output intensity, and the relation of these efforts to the proposed NexStar facility.

Work supported by DoE/NNSA

[1] S. Obenschain, *et al.*, submitted to Phys. Plasmas.
[2] J. Seely, *et al.*, Phys. Plasmas, **12** 062701 (2005).

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Investigation of High Z dopants to Mitigate Stimulated Raman Scattering in Gas Filled Hohlraums

J. L. Kline, D. S. Montgomery, H. A. Rose, S. R. Goldman
Los Alamos National Laboratory, Los Alamos, NM 87545

D. H. Froula, J. S. Ross
Lawrence Livermore National Laboratory, Livermore, CA

The successful achievement of thermo-nuclear ignition at the National Ignition Facility (NIF) depends on overcoming several key challenges. One such challenge is that of laser plasma instabilities. Laser plasma instabilities scatter the incident laser light reducing the energy converted to soft x-rays which are then coupled to the ignition capsule. If an insufficient amount of x-ray radiation is not coupled to the capsule, ignition can not take place. One approach to this challenge is to validate theories that show the possibility of mitigating laser plasma instabilities. Building an arsenal of such strategies provides a number of options for ignition designers in the event laser plasma instabilities scatter too much of the incident laser light. One such mitigation strategy is the use of High Z dopants in the hohlraum gas fill.

Gas bag experiments at the Helen laser a few years ago showed that the addition of a small amount of high Z dopant could significantly reduce laser plasma instabilities. More recently, theoretical work at Los Alamos National Laboratory provided a theoretical basis for the reduction in backscattered laser light. Thermal filamentation of the laser results in beam spray that in turn reduces stimulated Raman scattering. Since thermal effects depend strongly on Z^2, a small amount of a high Z dopant can have a large effect. To validate the theory, experiments are currently underway at the Omega laser in NIF relevant plasmas using gas filled hohlraum. Using the 3ω Transmitted Beam Diagnostic developed by Lawrence Livermore National Laboratory, the beam spray, as well as transmitted energy, from an interaction laser beam can be monitor while monitoring the stimulated Raman backscattered light as High Z material is added to the gas fill. In recent Omega experiments, a Xe dopant has been varied in a neopentane gas fill hohlraum. Details of the experiment and the results will be presented.

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Experimental Investigation of the Plasma Induced Laser Beam Smoothing on the ALISE Laser Facility

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The control of the laser coherence properties is essential in the context of inertial confinement fusion to achieve the more efficient coupling between the laser energy and the target. Previous theoretical and experimental works have underlined the ability of a plasma to reduce the laser coherence properties. At sufficiently high intensity the interplay between filamentation and forward stimulated Brillouin scattering (FSBS) is responsible for the observed coherence loss. At lower intensity, well below the filamentation threshold, the FSBS is initiated by multiple scattering of the laser light. It requires a longer length of plasma but it is assumed to not be associated to undesirable effects as strong angular spreading and enhanced backscattering. The experiment we present is devoted to this regime.

The interaction between a low density, millimetric plasma created from a Helium gasjet and a spatially incoherent laser beam has been studied on the ALISE laser facility at the CEA/CESTA, near Bordeaux (France). Dedicated diagnostics have been used to characterize the spatial and temporal coherence loss of the transmitted light. Both regimes, above and below the filamentation threshold, have been investigated and in both, the FSBS is shown to play a keyrole in the beam smoothing.

The plasma induced smoothing has been obtained without strong angular spreading of the transmitted light. The backscattering instabilities are shown to be negligible.

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Laser Plasma Instability Reduction by Coherence Disruption and Other Techniques-II

William L. Kruer
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Scott Wilks, Peter A. Amendt, Nathan Meezan, and L. J. Suter
Lawrence Livermore National Laboratory

Additional techniques to control laser plasma instabilities would enlarge the parameter space for ignition target designs on the National Ignition Facility. A possibility recently suggested[1] is to engineer coherence disruptions in NIF hohlraums, say, by modulations in the liner composition or by manipulation of the plasma flow. Further consideration is given to how to disrupt the coherence of the instabilities. We also explore other techniques for instability mitigation, including re-absorption of the scattered light and effects associated with oblique incidence. Finally we note that it is also important to minimize seeding the laser-driven instabilities, which can happen in various ways.

1. William L. Kruer, et. al., UCRL-SR-220853 (2005)

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Laser-Plasma Instabilities in NIF Target Design*

E. S. Dodd, B. Bezzerides, P. Bradley, D. F. DuBois, S. R. Goldman, M. J. Schmitt
Los Alamos National Laboratory
H. X. Vu
University of California, San Diego

Successful fusion ignition at the National Ignition Facility (NIF) depends on propagating laser energy through many millimeters of underdense plasma. Laser-plasma interactions (LPI) can cause reflectivity that effects holhraum energy, and filamentation and beam spray which effect drive symmetry on the capsule. Reflectivity can also result in damage to the laser system. Therefore, the understanding of LPI is critical for target design. In this poster we study LPI at plasma conditions existing in current NIF target designs using linear and nonlinear physics. Post-processing of LASNEX data and self-consistent simulations using pF3d will be used. Specifically, recent work on the inflation threshold of stimulated Raman scattering (SRS) reflectivity from trapped electrons has been added to pF3d (H.X. Vu, D.F. DuBois, and B. Bezzerides, "A Threshold for Superlinear Enhancement of Stimulated Raman Scattering by Electron Trapping," Phys. Rev. Lett., submitted (April 7, 2006)). Applying this to current designs at Los Alamos, we will estimate the relative growth of LPI between the inner and outer beams. Our analysis will show that beryllium plasma from the capsule increases the linear growth of SRS for the inner beam relative to the outer beam at late times. Estimates of the intensity threshold for SRS inflation will also be given using gain from a single speckle. Similar analysis can be used for ongoing LPI experiments, thus providing validation prior to experiments in 2010.

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Driven Electron Plasma Waves Relevant to Raman Scattering*

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

The saturation of Stimulated Raman Scattering (SRS) is investigated by externally driving an electron plasma wave in a one-dimensional electrostatic code. By isolating the plasma wave behavior in the absence of a laser, a clearer picture of the growth, saturation, and recurrence is seen. For the few cases we have done, the driven wave grows and saturates when wavebreaking occurs, that is, when trapped particles escape their initial buckets rather than executing numerous bounces. A nonlinear frequency shift and sidebands are also seen, but these do not appear to cause saturation because the saturated amplitude is greater than would be predicted by the frequency shift detuning. On the other hand, after the wave amplitude begins to decrease there is a recurrence of plasma wave growth. The peak amplitude of each recurrence is progressively lower. The recurrence time between growth and saturation seems to be due to the beating of the external drive with the frequency shifted large amplitude plasma wave. The main effect of the sidebands is to destroy the spatial coherence of the phase space and smooth it out. In simulations where the external driver is turned off before, or soon after, the initial saturation, the wave amplitude decays more slowly and does not display the periodic recurrence characteristic of the continuously driven case. A preliminary discussion of plasma wave convection will also be presented. The relevance of these simulations to fully self-consistent simulations using OSIRIS will be discussed as well as preliminary simulations of ion acoustic wave saturation.

* Work supported by DOE under grant number DE-FG52-03NA00065:A004.

Friday, June 9, 2006

8:30 -	9:30 AM	Invited Talk – M. Stevenson Session Chair: D. Hinkel
9:30 -	11:30 AM	Oral Session 9
11:30 -	11:35 AM	Adjourn
11:35 -	12:30 PM	Lunch

Morning Invited Talk 5

Speaker: M. Stevenson
8:30 am – 9:30 am

Session Chair: Denise Hinkel,
Lawrence Livermore National Laboratory

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Proton Backlit Observations of Filamentation in Homogeneous Plasmas

R.M. Stevenson,[1] M. Borghesi,[2] D.J Hoarty,[1] S. James,[1] C. Cecchetti,[2] R. Jung ,[3] O. Willi ,[3] P. Hobbs ,[1] J. Lockyear ,[1].
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The use of phase plates for beam smoothing to rectify largescale intensity variations on laser systems is well established. However, many laser plasma experiments can also be sensitive to the fine scale speckle resulting from the use of these devices. A series of experiments using phase plate smoothing to examine the propagation of an axial laser beam through gasbag targets were conducted on the HELEN laser facility several years ago (RM Stevenson *et al*, Phys. Plasmas **11**, 2709, 2004). It was postulated at the time that the observed effects on the Stimulated Raman Backscatter were a result of beam filamentation. Subsequent work (Meezan *et al*, Phys. Plasmas **11**, 5573, 2004) showed that the streaked spectral data could be explained without invoking filamentation. Observations of the variation in backscattered energy with electron density (gas composition) showed a significant change close to the point predicted to be the threshold for filamentation. The object of this new work was to attempt to directly observe the formation of filamentary structure around this calculated threshold using a proton backlighting technique (M.Borghesi *et al*, Phys. Plasmas, **9**, 2214, *2002)*. The campaign utilised the same laser parameters as in the previous experiment (1ns 'temporally top hat', 300J at 527nm) and examined the effects in neo-Pentane (C_5H_{12}) filled gasbag targets over a range of gas pressures (electron densities). The proton backlighting source was produced using a synchronised Chirped Pulse Amplification (CPA) system firing 30J (1053nm) in 0.5ps onto a 20μm thick Gold substrate. The data appears to show 'filamentary' like structure appearing at the predicted threshold. However, as the electron density is increased, the configuration of the structure changes significantly from divergent to parallel with respect to the incident light. This may suggest that at higher electron densities, the divergence of the 'filaments' increases rapidly and they 'vanish' and/or a different focussing mechanism dominates.

Oral Session 9

9:30 am – 11:30 am

Session Chair: Denise Hinkel,
Lawrence Livermore National Laboratory

36th Annual Anomalous Absorption Conference
Jackson Hole, Wyoming, USA
June 4-9, 2006

Modification of Laser Beam Coherence Properties During the Propagation Throughunderdense Plasmas

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Inertial fusion experiments require to control the laser coherence properties to obtain an efficient deposition of the laser energy on the target. This control is currently achieved by optical smoothing techniques. However, previous works suggest that the interaction between a spatially incoherent beam and a low density plasma could be an attractive way to provide laser beam smoothing. At sufficiently high intensity, the reduction of the beam coherences results from the interplay between filamentation and forward stimulated Brillouin scattering (FSBS). This regime lead to a strong reduction of the temporal coherence but it is associated with filamentation and strong angular spreading of the transmitted laser light. This paper considers a lower intensity regime where the selffocusing threshold is not reached. In such a regime, only collective processes from an ensemble of hotspots can explain the observed coherence loss. Using a statistical model for the propagation of partially coherent laser beams through plasmas, one shows that laser scattering on nonstationary density fluctuations reduces the beam spatial and temporal coherences after propagation of a few speckle lengths. Three dimensional numerical simulations using the interaction code PARAX show how this laser beam multiple scattering initiates FSBS, leading to the spatiotemporal smoothing of the transmitted light. This paper presents the main analytical results obtained using the statistical model and a comparison to numerical simulations with a paraxial code. We show that using low intensity lasers smoothed by only random phase plates enables to avoid deleterious effects of filamentation, as important angular spreading of the transmitted light, and to obtain in the same time an efficient temporal smoothing. Moreover, such smoothing can be achieved in low density plasmas where energy losses due to backscattering and absorption are not too important.

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Design of a Potential, Single Quad Intensity Scaling Experiment for LIL

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We have simulated the NIF early light (NEL), gas-filled halfraum experiments done by LANL (J. C. Fernandez et al, Physics of Plasmas, *in press*) using the radiation/hydrodynamics code Hydra. Separate calculations were performed on the Hydra results to determine the T_r as measured by Dante as well as the linear LPI gains.

A modified LANL halfraum design, able to accept larger diameter beams, was also simulated with the same power and temporal history used in the LANL NEL campaign. The large amounts of backscattered light in the aforementioned LANL NEL experiments coincide with large linear gain coefficients. Increasing the spot diameter of the beam in the modified halfraums reduces the calculated linear gain of the backscattered light and should reduce the amount of backscattered light as well. It may be possible to perform such an experiment on the CEA facility LIL (Fleurot et al, Fusion Engineering and Design, vol. **74**, pp. 147-154 (2005)).

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Laser-Plasma Interactions in 2010 Ignition Targets*

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Targets planned for the 2010 campaign at the National Ignition Facility (NIF) are currently undergoing re-designs so that they not only provide good symmetry, but also hold hope for benign laser-plasma interactions. These targets hold a capsule with a beryllium ablator, are filled with He at 1.3 mg/cc, have "cocktail" walls composed of 50% gold/50% uranium with a 0.2 μm gold liner, and have a 25 μm CH liner around the laser entrance hole (LEH). Designs both without (S. M. Pollaine, LLNL) and with (D. A. Callahan, LLNL) a shine shield are under consideration for the 2010 ignition campaign. Gain exponents for Brillouin and Raman backscatter have been reduced to ~ 20 or less in these new designs. Simulations of beam scatter and propagation have been performed using pF3D. Gain exponents, beam spray, and reflectivity as a function of beam conditioning will be presented for these new designs.

*Work performed under the auspices of the U.S. Department of Energy by the University of California Lawrence
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Laser Absorption in Spherical Target Experiments on OMEGA

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Time-resolved and time-integrated absorption measurements on OMEGA implosion experiments show intriguing details that differ markedly from predictions based on hydrodynamic simulations. These differences primarily occur during the first 200 to 300 ps of the laser pulse and are most noticeable in rapidly rising laser pulses such as top-hat (square) pulses with 50-ps/decade rise times or pulses with a short picket-fence pulse (~80-ps FWHM) preceding the main pulse. Under these irradiation conditions, hydrodynamic simulations predict a much lower initial absorption (conversely much more scattered laser light) than is observed experimentally. In addition, the predicted neutron bang time is delayed relative to observed bang times. Hydrodynamic simulations using an *ad hoc* time-varying flux limiter to artificially match the observed initial absorption leads to improved predictions for the neutron bang time. While these effects are subtle, they may have significant implications for simulations of the initial plasma formation and subsequent implosion dynamics and may require improved thermal electron transport modeling at this stage.

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Crossed Beam Power Transfer in NIF Ignition Targets and the Two-Color Option

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Theory has predicted and experiments have shown that stimulated forward Brillouin scattering (FSBS) can cause power transfer between two laser beams intersecting in plasma. Maximum transfer occurs when the beat ponderomotive force between the laser beams resonantly drives an ion acoustic wave. For two laser beams with the same frequency, this occurs when the plasma flow velocity component in the direction of their difference k-vector is sonic.

A study of the 2002 point design showed that significant power transfer might be expected between the inner and outer beams (~20%) despite the mach one resonant surface lying outside the beam crossing volume. The finite ion-acoustic resonance width of the CH plasma from the LEH lip-liner was responsible for non-resonant FSBS gain. That study showed that beam power transfer in the supersonic nozzle-like flow outside the LEH should be suppressed by a relative shift of the inner beams of 1-2Å (at 1ω) relative to the outer beams.

Such shifts are well within the amplification bandwidth of the laser glass and so can be provided at the price of an additional oscillator at the NIF front-end and modified mounts for the frequency conversion crystals. However, additional considerations apply when specifying the appropriate frequency shift for NIF. SSD on the beams spreads the effective resonance width. Subsonic flows inside the hohlraum can be brought into resonance by sufficiently large red shifts of the inner beams. Unlike the flows outside the LEH, these flows are sensitive to the design.

We show analysis of a range of ignition designs and show that an adjustable shift is appropriate for NIF. Adjustment of the shift can be used to tune away the power transfer, or if advantageous, used to deliberately alter the beam power balance.

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Simulations of Recent Omega Fill Tube Experiments

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Fill tubes will be used to inject liquid DT into the interior of inertial confinement fusion (ICF) capsules in the first ignition experiments on the National Ignition Facility (NIF) laser. Hydrodynamic instabilities cause the perturbation due to the stalk to grow during an implosion. Simulations will be used to ensure that the perturbations resulting from fill tubes do not lead to a significant reduction in the yield of a NIF implosion. Experiments in which a plastic stalk is attached to a non-cryogenic capsule have been carried out on the Omega laser. The capsules used in these experiments have a small amount of titanium placed in the inner layers of the plastic shell to diagnose the growth of the jet. The experimental x-ray images clearly show a jet for larger stalk diameters. We present the results of 2D simulations of x-ray emission from Omega capsule implosions with stalks of the same size as used in the experiments. The emission from the jet crosses the capsule at similar rates in the experiments and the simulations. The dependence of the x-ray images (experimental and simulated) on the initial stalk size will be discussed.

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[1] This work was performed under the auspices of the U.S. Department of Energy by the University of California Lawrence Livermore National Laboratory under contract No. W-7405-Eng-48.